Journal of Plant Development Sciences

(An International Monthly Refereed Research Journal)

Volume 10 **Number 12** **December 2018**

Contents

REVIEW ARTICLE

A REVIEW ON AVAILABILITY, UTILIZATION AND FUTURE OF EGG PLANT GENETIC RESOURCES IN INDIA

Anushma, P.L.*, Rajasekharan, P.E. and Singh, T.H.

ICAR-Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru-560089, Karnataka, India
Email: anushma.p.l@gmail.com

Received-07.12.2018, Revised-26.12.2018

Abstract: Egg plant is one of the most important indigenous vegetable crops of India, cultivated in the tropical and subtropical regions of the world. The global production of the crop has been seriously affected by various biotic and abiotic stresses and development of pest and disease resistance is a major challenge in brinjal breeding. Many wild species of the genus Solanum are available in the country, which have not been efficiently utilized in breeding programs. The present review attempted to gather information on the genetic resources of egg plant available, their distribution, sources of resistance to various pests, diseases and abiotic stresses and opportunities in their utilization for crop improvement programs using conventional and biotechnological interventions.

Keywords: *Solanum*, Genetic resource, Stress, Utilization

INTRODUCTION

Egg plant (*Solanum melongena* L.), also known as aubergine or eggplant is one of the most important vegetables cultivated throughout the warmer regions of the world. The crop is widely cultivated in the tropical and subtropical regions of both the hemispheres, especially in West Indies and southern United States. In India, Brinjal is the fourth important vegetable in terms of production (8.1%) after potato, tomato and onion while India enjoys second largest position in the world contributing 27.55 per cent of global production. Yet the productivity (17.5t/ha) is much lower than the word average (25t/ha), with only 0.01% share in the world export (Vanitha *et al*., 2013; APEDA, 2011). India's share in the world export of egg plants have drastically come down from 0.54% (2006) to 0.03% during 2010 wherein the demand from the major importing countries like Canada, Bahrain and Netherlands fell down sharply. This is because of various factors especially, due to the inferior quality of the produce through insect infestation. Though many varieties have been released with better yield and quality, development of pest and disease resistance is a major challenge in brinjal breeding.

Solanum Linnaeaus is one of the largest diversified groups of the Solanaceae family with more than 1250 species distributed throughout the tropics and sub-tropics (Mabberley, 2008). Although many researchers have varied opinion regarding the origin of egg plant, there is consensus that India or Indo-China is the Centre of diversity (Bhaduri 1951; Vavilov 1951; Zeven and Zhukovsky 1975; Lester and Hasan1991). Occurrence of about 42 species of *Solanum* has been reported in India (Deb, 1980). But the wild relatives of egg plant have not been utilized to their full potential in breeding programs due to lack of knowledge on their distribution, potential utility and reproductive biology. Egg plant is prone to many diseases such as *Fusarium* and *Verticillium* wilts, bacterial blight, *Phomopsis* blight, little leaf and nematodes (Gowda *et al*., 1974, Gopinath and Madalgeri, 1986, Sihachakr *et al*., 1993). The cultivated brinjal shows tolerance to majority of its pests like the shoot and fruit borer (*Leucinodes orbonalis*), leaf hopper (*Amrasca biguttula*), aphids (*Aphis gossypii*) and *Epilachna* beetles, but at rather lower levels (Raj and Kumaraswamy, 1979, Bindra and Mahal, 1981, Sambandam and Chellaiah, 1983, Messiaen, 1989, Daunay *et al*., 1991, Rotino *et al*., 1997). Use of wild species and relatives in the crop improvement programmes to gain vigour and resistance has been well recognized (Sarvayya, 1936). In 1977, egg plant was included in the list of species having priority for genetic resources preservation (Daunay *et al*., 1997). Eggplant ranks high among crops whose wild gene pools are poorly represented in ex situ collections and need urgent conservation (Muteqi *et al*., 2015). The present review attempts to gather information on distribution of genetic resources of egg plant available in India, their potential uses and challenges in their utilization in the crop improvement programmes.

Origin and distribution

India is considered as the centre of diversity for egg plant by many scientists. There are about 28 non-tuberous *Solanum* species found wild in india viz., *S.acculeatissimum, S. albicaule, S. arundo, S. barbisetum, S.dubium, S. dulcamara, S. elaegnifolium, S.erianthum, S. giganteum, S. glaucophyllum, S. gracilipes, S. grandiflorum, S. hispidum, S. incanum, S. indicum, S.kurzi, S. melongena var insanum, S. myriacanthum, S. nigrum, S. pubesense, S.sysimbrifolium, S.spirale, S. stramonifolium (*syn. *S. ferox), S. surattense (*syn. *S. xanthocarpum), S.torvum, S.trilobatum, S. vagnum and S. viarum (*syn. *S. khasianum*). In India, western

*Corresponding Author

and eastern peninsular regions and north eastern region exhibit maximum species diversity (Arora and Nayar, 1984). *Solanum incanum*, reported as a progenitor of *S. melongena* by many workers (Lester and Hasan, 1991) is widely distributed in at least 10 habitats in India (Arora and Nayar, 1984), especially in the Punjab and Kumaun hills upto 1200 m, Rajasthan and Sourashtra in Gujarat and is closely related to the semi wild weedy form *S. melongena* var. *insanum*. *Solanum acculeatissimum*, a very spiny shrub is seen wild in Kerala and Assam in damp and waste places. *S. dulcamara* or bitter sweet is a climbing shrub, frequently found in the temperate Himalayas from Kashmir to Sikkim at altitudes of 1200-2400 m. *S. elaegnifolium*, also known as white horse nettle is an exotic deep root spiny weed native to tropical America and naturalized in India. It is met within cultivated fields and gardens of Coimbatore. *S. erianthum*, commonly called as potato creeper, is shrub or small tree upto 6m tall, found growing throughout the tropical and subtropical India and the Andamans. It is also cultivated in south India for its fruits which are eaten in curries.

Solanum ferox, commonly called as hairy fruited egg plant, is a stout sub erect prickly herb, found in tropical parts of eastern India from Assam southward into the peninsular India and in the Andaman islands. *S. giganteum* is a spiny shrub 3-7m tall, occurring in the Western Ghats in Maharashtra and in the hills of South India at altitude of 300-2000m while *S. hispidum* is a native of South America, naturalized in the ravines of Dehradun and Mussoorie. Poison berry, the *Solanum indicum*, is a very common spiny herb found throughout the warmer parts of India upto an elevation of 1500m. *S. khasianum* (*S. viarum*) is a stout, much branched undershrub found in Khasi, Jaintia and Naga hills of Assam and Manipur upto an altitude of 1850 m. The black nightshade or *S. nigrum* is a herbaceous weed throughout India, in dry parts upto an elevation of 2100m. *Solanum seaforthianum* commonly known as Potato creeper is believed to be a native of dry forests and thorn scrub of islands in the West Indies and coastal northern South America in Columbia and Venezuela (Wagner *et al*., 1999, Nee, 1999, Knapp, 2010). But it is believed that the species have broader native distribution range viz., Florida, Mexico, Central America, the West Indies, Venezuela and Columbia (IISG, 2008, Gallagher *et al*., 2010, USDA-ARS, 2014, USDA-NRCS, 2014). Sekhar (2012) reported its occurrence in various parts of the country like, Andhra Pradesh, Jammu & Kashmir, Himachal Pradesh and north eastern states like Assam, Manipur, Meghalaya, Mizoram, Sikkim, Tripura and West Bengal. *S. surattens* commonly called as the yellow berried nightshade is commonly found throughout India while *S. sysimbrifolium* is a native of central and South America (Argentina, Southern Brazil, Paraguay, Uruguay, Bolivia and Colombia). The species is known to be distributed in North America (Canada, Mexico, United States), Europe (Spain and Netherlands), Asia (India, china, Taiwan), Africa (South Africa, Congo, Swaziland) and Australia. In india, *S. sysimbrifolium* is found distributed in Andhra Pradesh, Assam, Bihar, Kerala, Karnataka, Maharashtra, Manipur, Orissa, Punjab, Sikkim, Tripura, Uttar Pradesh and West Bengal. *S. torvum* known as Turkey berry is a small shrub native to West Indies, India, Myanmar, Thailand, Philippines, Malaysia, china, and tropical America (Nasir, 1985).

Sources of resistance

Biotic stresses

Low productivity in brinjal is mainly attributed by the losses due to insect pest infestation. Among the various pests, the shoot and fruit borer is the most destructive ones causing up to 70 per cent of yield loss (Srinivasan, 2009) in almost all the brinjal growing belts (Datta *et al*., 2011). Lack of resistance source in the cultivated *S. melongena* germplasm is the major bottle neck in the resistance breeding programme for shoot and fruit borer resistance (Pugalendhi *et al*., 2010). Several studies involving wild species of egg plant have been attempted for borer resistance (Gowda *et al*., 1990b, Anis *et al*., 1994, Behera and Singh, 2002, Praneetha, 2002). The wild species of brinjal like *S. sisymbrifolium* (Lal *et al*., 1965, Dhanker *et al*., 1979), *S. integrifolium*, *S. xanthocarpum* and *S. nigrum* have earlier been found free from the borer (Lal *et al*., 1976, Rao and Baksh, 1981). Pugalendhi (2010) reported that sexual hybridization of susceptible egg plant genotype EP65 with the resistant source *S. viarum* (*S. khasianum*) and selfing up to F9 generation could reduce the shoot and fruit borer infestation to a negligible level in the genotype. Also, the F9 recorded the highest peroxidase activity, poly phenol oxidase activity and equivalent quantity of total phenol to that of *S. viarum*. Thus the presence of these biochemical constituents acted as stimulants of resistance mechanism against shoot and fruit borer. The genotypes with high or moderate levels of these biochemical compounds suffered less borer infestation (Kkosuge, 1969, Praneetha, 2002 and Prabhu, 2004).Some resistant local brinjal forms have been identified in north western India which is the region wherein domestication of brinjal from *S. incanum* is believed to be taken place (Mathur *et al*., 2012; Samuels, 2013). Jassids, also known as egg plant leaf hoppers are reported to be the serious pests of brinjal in the tropical and subtropical regions due to the prevailing congenial climatic conditions (Nagia *et al*., 1993; Mall *et al*., 1992). It is reported that brinjal varieties viz., Var Dorli, Jumbli and Manjari Gota are resistant to jassids. Hairiness on the leaf surfaces is said to be one of the factors for resistance (More, 1982). In the recent years, damage due to a group of gall forming insects has been reported in egg plant. The infestation due to gall insects in egg plant flowers ranged from 2- 44 %

(Tewrai *et al*., 1987). The wild species of brinjal, *S. macrocarpon* is reported resistant to gall midges wherein the biochemical mechanisms governing resistance need to be investigated (Kumar *et al*., 2010).

Egg plant is infected by many pathogens. Resistance to bacterial wilt caused by *Ralstonia solanacearum* (Li, 1988; Daunay *et al*., 1991; Goth, 1991; Ali *et al*., 1992a, Hanudin *et al*., 1993; Peter *et al*., 1993) and fruit anthracnose by *Colletotrichum gloeosporioides* (Sitaramaiah *et al*., 1985, Kaan, 1973, Messiaen, 1989) is available within some varieties of *S. melongena*. But resistance to bacterial wilt has become insufficient in hot planting seasons and poorly drained soils (Ano *et al*., 1991). For rest of the diseases like *Verticillium* and *Fusarium* wilts and *Phomopsis* blight, only partial resistance or tolerance is reported in cultivated brinjal (Dhawan and Sethi, 1976; Nothman and Yephet, 1979; Yamakawa and Mochizuki, 1979; Messiaen, 1989; Ali *et al*., 1992b). Resistance to bacterial wilt has been reported in the wild species of brinjal viz., *S. torvum*, *S. nigrum*, *S. xanthocarpum* and *S. sisymbrifolium* (Sugha *et al*., 2002). Commercial propagation using rootstocks like *S. mammosum*, *S. integrifolium* and *S. torvum* is found beneficial in egg plant to avoid damage by bacterial wilt (Tamura *et al*., 2002). But it is also reported that though *S. integrifolium* is highly resistant to *Fusarium* wilt, its resistance to *R. solanacearum* is not sufficient to protect the scions under congenial conditions of the disease (Iwamoto *et al*., 2007). But the disease was effectively controlled by making interspecific hybrids between *S. integrifolium* selections and brinjal genotypes with some resistance to bacterial wilt. Leaf blight and fruit rot caused by *Phomopsis vexans* is a major constraint in egg plant production as it reduces the yield and marketable value by 20-30 per cent (Jain and Bhatnagar, 1980, Kaur *et al*., 1985). Kalda *et al*. (1976) found that *S.xanthocarpum*, *S.indicum*, *S.gilo*, *S.khasianum*, *S. nigrum* and *S. sisymbrifolium* were highly resistant to *Phomopsis* blight. Little leaf is nearly becoming a limiting factor for egg plant cultivation throughout the country. The wild species *S. viarum* is reported to be immune to the little leaf whereas *S. inacanum* and *S. sisymbrifolium* were found resistant (Anjaneyalu and Ramakrishnan, 1968; Chakrabarti and Choudhary, 1974). There are also reports that wild species *S. integrifolium* and *S. gilo* showed resistance to little leaf disease due to their hyper sensitive reaction to the pathogen. Also, the F1 progenies of Pusa Purple Long with these two species behaved like their resistant parents in the disease reaction. Among the varieties of brinjal, Pusa Purple Cluster was only variety observed to be resistant while Nurki, Bourad Local No. 4 and Chikkalgaon Local No. 1 were moderately resistant (Mayee and Munshi, 1973; Chakrabarti and Choudhary, 1974; mote *et al*., 1976 and Gill *et al*., 1978). *S. linnaeanum*, *S. sisymbrifolium* and *S. torvum* are reported to be sources of resistance to *Verticillium dahliae*. The sexual interspecific hybrid of egg plant carrying tolerance to *Verticillium* wilt was obtained using *S. linnaeanum* (Collonnier, 2001). The expression profiling of *S. torvum* responses to nematode infection revealed sesquiterpenes and chitinases as major effectors for nematode resistance (Bletsos *et al*, 2013). Though resistant sources are available in plenty among the wild species, the information regarding the gene responsible for these traits and their inheritance pattern is scanty.

Abiotic stresses

In a comparative study among three wild eggplant species, *S. aethiopicum*, *S.* sisymbriifolium, and *S. torvum*), *S. sisymbriifolium* lines were found as more tolerant to salinity than the other two wild species (Yasar ve Ellialtıoglu, 2008). *S. linnaeanum* is reported to have tolerance to salt stress (Daunay *et al*., 1991; Collonier *et al*., 2001) however, little is known about the mechanism in response to salt stres*S.* When leaf cell arrangement of cultivated *Solanum melongena* was compared with the drought tolerant wild species *Solanum* khasianum, higher amount of spongy mesophyll cells and lower height of palisade mesophyll cells in the petioles were observed in the susceptible eggplant genotypes. Also, the drought resistant wild genotypes had higher tissue ratio and (1-1.5) than the susceptible cultivated genotypes (0.50-0.53). In the wild *S. khasianum*, the stomatal number was 45–50% less as compared to cultivated genotypes on both lower and upper side of the leaf, greatly reducing evapo transpirational losses (Kulkarni *et al*., 2008). Grafting egg plants on *S. torvum* enhanced both drought and flood tolerance and improved the growth and fruit quality (Tsay and Lin, 2005). Traits related to frost damage have been observed in *S. mammosum*, *S. viarum* and *S. grandiflorum* (Baksh and Iqbal, 1979).

Table 1. Solanum wild species resistant to diseases and pests.

Species	Disease	Pests	References
S. aethiopicum	[(1)]*Phomopsis vexans*, [(2)]*Fusarium oxysporum*, [(3)]*Ralstonia solanacearum* [(4)]Mycoplasma	[(5,6)]*Leucinodes orbonalis*	[(1)]Ahmad,1987, [(2)]Yamkava and Mochizuki, 1979, [(3)]Sheela *et al*.,1984 [(5)]Khan *et al*., 1978, [(6)]Chellaiah and Sreenivasam, 1986

S. hispidum	[1]*Verticillium* dahliae & *Verticillium alboratum*, [2]*Ralstonia solanacearum*, [3]*Meloidogyne* sp. [4]Mycoplasma	Nil	[1]Daunay *et al*., 1982, [2]Hebert, 1985 [3]Daunay and Dalmaso, 1985, [4]Rao,1980
S. incanum	[1]*Phomopsis vexans*, [2]*Fusarium oxysporum*,	[3,4,5]*Leucinodes orbonalis*	[1]Rao,1981, [2]Yamkava and Mochizuki, 1979, [3]Singh, 1972 [4]Khan *et al*., 1978, [5]Chellaiah and Sreenivasam, 1986
S. indicum	[1]*Phomopsis vexans*,	[2,3]*Leucinodes orbonalis*	[1]Kalda *et al*., 1976 [2]Behera *et al*., 1999 [3] Behera *et al*., 2002
S. linnaeanum	[1]*Verticillium dahliae* & *Verticillium alboratum*, [2]Colletotrichum coccoides		[1]Daunay *et al*., 1991, [2]Pochard and Daunay, 1977
S. macrocarpon		[1]Tetrannychus urticae, [2]*Leucinodes orbonalis*	[1]Shaff *et al*., 1976, [2]Gowda *et al*., 1990
S. mammosum	[1]*Fusarium oxysporum*	[2]*Leucinodes orbonalis*,[3]*Epilachna* viginctioctopunctata [4]*Aphis gossypii* [5] *Tetranychus cinnabarinus*	[1]Telek *et al*., 1977 [2]Baksh and Iqbal, 1979, [3]Beyries, 1979 [4]Smabandam and Chellaiah, 1983 [5]Shalk *et al*., 1975
S. nigrum	[1]*Phomopsis vexans*, [2]*Ralstonia solanacearum*	Nil	[1]Kalda *et al*., 1977 [2]Hebert, 1985
S.sisymbrifolium	[1] *Phomopsis vexans*, [2,3]*Verticillium dahliae* & *Verticillium alboratum*, [4]*Ralstonia solanacearum*, [5]*Meloidogyne* sp.	[6]*Leucinodes orbonalis* [7] *Tetranychus cinnabarinus*	[1]Kalda *et al*., 1977 [2,5]Fassuliotis and Dukes, 1972 [3]Collonnier, 2001 [4]Mochizuki and Yamakawa, 1979b [6]Lal *et al*., 1976 [7]Shalk *et al*., 1975
S. torvum	[1] *Verticillium dahliae* & *Verticillium alboratum*, [2]*Ralstonia solanacearum*, [3]*Meloidogyne* sp. [4]Mycoplasma	[5] *Epilachna viginctioctopunctata*	[1]Daunay *et al*., 1991, [2]Hebert, 1985 [3]Daunay and Dalmaso, 1985, [4]Rao,1980 [5] Sambandam *et al*., 1976
S. viarum	[1] *Phomopsis vexans*, [2]Mycoplasma	[3]*Leucinodes orbonalis*, [4] *Epilachna viginctioctopunctata*	[1]Kalda *et al*., 1977 [2]Datar and Ashtaputre, 1984 [3]Lal *et al*., 1976 [4]Sambandam *et al*., 1976
S. violaceum	[1] *Phomopsis vexans*, [2]*Fusarium oxysporum* [3]*Meloidogyne* sp.	Nil	[1]Ahmad, 1987, [2]Yamakawa and Mochizuki, 1979 [3]Sonawane and Darekar, 1984

Limitations in exploiting wild *Solanum*s in egg plant crop improvement

Crossability

Although crossability between *S. melongena* and other *Solanum* species have been studied over the past few years, utilization of these wild species for introgression of resistance traits to the modern day egg plant cultivars has got limited success. Based on the available information on crossability between related species of egg plant, there is no natural crossing among cultivated and wild species of brinjal. Also, under forced crossing situations, even though crossing was possible, the viability was not retained. Sihachakr *et al*., 1994 reported that *S. melongena* can be crossed sexually with many species of same subgenus Leptospermonum. Eleven *Solanum* species were grouped into three groups by Nishio *et al* (1984) based on their interspecific

compatibility wherein the first group included *S. melongena*, *S. incanum* and *S. macrocarpon*. The *S. integrifolium*, *S. gilo* and *S. nodiflorum* constituted the second group while *S. indicum*, *S. mammosum*, *S. torvum*, *S. sysymbrifolium* and *S. toxicarium* were included in the third group. They opined that crosses were combatable within and between the first and second groups but were otherwise incompatible. There are varied opinions on the crossability relation among the *Solanum* species. Rao (1979) reported that *S. melongena* cultivar as female parent when hybridized with *S. melongena* var. *insanum*, *S. incanum*, *S. integrifolium* and *S. gilo* produced viable seeds. But it did not hybridize with *S. indicum*, *S. sisymbrifolium* and *S. zuccagnianum*. Behera and Sigh (2002) reports successful crossing in *S. melongena* using *S. indicum* as pollen parent while the reciprocal crossing progenies died within 15 days of germination. Amomg the nineteen species of *Solanum* used for egg plant crop improvement worldwide, only four species viz., *S. incanum*, *S. linnaeanum*, *S. aethiopicum* and *S. macrocarpon* have been used successfully for developing progenies with partial fertility (Daunay and Lester, 1989). *S. xanthocarpum* and *S. incanum* are crossable with egg plant producing fertile or partially fertile hybrids (Singh, 1972). *S. melongena* was freely crossable with *S. incanum* and the hybrid exhibited field resistance to shoot and fruit borer and leaf rot (Siddiqui and Khan, 1979). *S. viarum*, a closely related wild species of egg plant is cross compatible with the cultivated egg plant (Pugalendhi *et al*., 2010). In a study carried out at IIVR, Varanasi, the results indicated that except *S. incanum*, all other species used for crossing program like *S. indicum*, *S. nigrum*, *S. sisymbrifolium* and *S. torvum* were incompatible with cultivated egg plant varieties. Fruit set was not obtained in crosses involving wild species as female parents. Rao and Baksh (1981) reported 60 % fruit set and 65 % seed germination when Pusa Purple Long was crossed by *S. integrifolium* as male parent. Although successful crossings involving wild species are reported, sterility is a major limiting factor in their utilization in crop improvement programs. For example, crosses were made by Rao (1979) using ten *Solanum* species viz, *S. melongena*, *S. melongena* var. *insanum*, *S. incanum*, *S. indicum*, *S. xanthocarpum*, *S. integrifolium*, *S. gilo*, *S. zuccagnianum*, *S. sisymbrifolium* and *S. khasianum* in all possible combinations. Among the ninety crosses made, only 39 resulted in fruit set, four produced parthenocarpic fruits and in the remaining 47 crosses, there was no fruit set. The partial sterility of interspecific hybrids of egg plant with its allied species may be linked to the self incompatibility problems brought by the wild parents and not by egg plant being self incompatible (Daunay *et al*., 1991).

Table 2. Inter-specific crossability studies in egg plant

Parents involved	Status of hybrid	References
S. melongena x *S. aethiopicum*	Fertile hybrids	Ignatova, 1971, Ano *et al*., 1991
S. melongena x *S. gilo*	F1 hybrids obtained Sterile F1 hybrids	Ali and Fujieda, 1990 Nasrallah and Hopp, 1963, Omidiji, 1981
S. melongena x *S. hispidum*	Sterile F1 hybrids	Rao, 1980
S. melongena x S. *indicum*	Obtained F4 plants Partially fertile Sterile F1 hybrids	Rao and Kumar (1980), Rao and Rao (1984) Krishnappa and Chennaveeraiah (1965), Rajasekaran (1968), Narasimha Rao (1968), Rangaswamy and Kadambavanasundaram (1973a,b, 1974a,b) Rao and Rao (1984)
S. melongena x *S. insanum*	Obtained F1 hybrids	Swaminathan (1949), Mittal (1950), Babu Rao (1965), Ali and Fujieda (1990)
S. melongena x *S. integrifolium*	Obtained F1 hybrids Partially fertile hybrids Sterile F1 hybrids	Rao and Baksh (1979) Hagiwara and Iida (1938, 1939), Tatebe (1941), Miwa *et al*. (1958), Kataezin (1965), Narasimha Rao (1968), Ludilov (1974) Berry (1953), Fukumotoh (1962), Rao and Baksh (1981), Kirti and Rao (1982),
S. melongena x *S. khasianum*	Obtained F1 hybrids	Sharma *et al*., 1984

S. melongena x *S. macrocarpon*	Fertile F1 and F2 plants Sterile plants	Schaff *et al*., 1982 Rajasekaran (1961), Wanjari (1976),Gowda *et al*. (1990)
S. melongena x *S. sisymbrifolium*	Sterile plants	Bletsos *et al*., 1998
S. melongena x *S. surattense*	Sterile F1 hybrids	Rao and Rao, 1984
S. melongena x S. *torvum*	Very low fertility in F1plants	McCammon and Honma (1983), Blestsos *et al*. (1998)
S. melongena x *S. xanthocarpum*	Partially fertile hybrids Sterile F1 hybrids	Swaminathan (1949) Rajasekaran (1968, 1971), Sarvayya (1936), Hiremath (1952)
S. melongena x *S. zuccagnianum*	Sterile F1 hybrids	Rajasekaran and Sivasubramanian (1971)

Seed dormancy

Solanum species are propagated mainly through seed*S.* But the seeds of majority species possess dormancy for extended period*S.* In *S. incanum*, the reduction in seed germination is due to its hard seed coat (Joshua, 1978). Prolonged dormancy upto 39 years was observed in buried seeds of *S. nigrum* in Britain (Edmonds and Chweya, 1997). Primary dormancy was also a problem in freshly harvested *S. nigrum* (Bithell *et al*., 2003). In *S.* aethiopicum, embryo dormancy is reported by which, it takes 4 to 5 months for germination (Abdoulaye, 1992). Uniform seed germination ia major constraint in *S. torvum* that has limited its use in breeding programs (Ginoux and Laterrot, 1991). The dormancy *S. torvum* can be overcome by 12 hour soaking, 30 minutes of prewashing, prechilling at 5 °C for one day , or treatment with 0.1 per cent KNO3 or 0.01 per cent GA3 (Hayati *et al*., 2005)

Opportunities in utilization

Many egg plant wild relatives have been insufficiently studied but have great potential as sources of useful genes (Daunay, 2013). The major bottle neck of using wild species for introgression of agronomically important traits into the cultivated egg plant is crossability. Barriers on crossability can be overcome through conventional and biotechnological interventions. Adoption of bridge crossing through related species can be a useful method to overcome crossability barriers for introgression of beneficial traits into cultivated egg plants. Also, Use of wild species as rootstocks can also be adopted in egg plant to minimize damages due to various biotic and abiotic stresses. Since egg plant responds well to the tissue culture, especially plant regeneration, biotechnological methods can play important role in exploiting the genetic resources in crop improvement programs (Collonnier *et al*., 2001).

Somatic hybridization

Production of somatic hybrids through protoplast fusion has proved promising for introducing beneficial traits. Transfer of resistant traits by somatic hybridization has been attempted by many researchers (Guri and Sink, 1988; Sihachakr *et al*., 1989, Stattman *et al*, 1994, Jarl *et al*., 1999). In egg plant, Mesophyll tissues have been the primary source of high quantity protoplasts (Bhatt and Fassuliotis, 1981; Jia and Potrykus, 1981). The first somatic fusion of *S. melongena* with *S. sisymbrifolium* resulted in 21 aneuploid somatic hybrids which had only the *S. sisymbrifolium* chloroplast genome. Though they showed high resistance to root knot nematodes and red spider mites, due to hybrid sterility, these hybrids had limited utility in breeding programmes (Gleddie et al., 1986). Somatic hybrids of S. melongena with S. khasianum were produced by elecrofusion by Sihachakr et al., 1988 which contained the egg plant ctDNA type. Tetraploid somatic hybrids of egg plant with *S. torvum* were produced by chemical and electrofusion wherein most of them had the egg plant ctDNA type, and were all resistant to *Verticillium* wilt, nematodes and partially resistant to spider mites (Guri and Sink, 1988a; Sihachakr et al., 1994). Tamura *et al*., 2002 could successfully produce somatic hybrids by electrofusion between *S. integrifolium* and the bacterial wilt tolerant wild egg plant *S. violaceum*. Tetraploid somatic hybrids produced by electrofusion of brinjal with *S. aethiopicum* or *S. integrifolium* protoplasts demonstrated that partial genetic recombination occurred between the genome of egg plant and those of allied species (Toppino *et al*., 2009). Highly fertile somatic hybrids of egg plant with *S. aethiopicum* were produced by electrofusion wherein better pollen fertility (30-85%) was observed in somatic hybrids when compared to their sexual counter parts (20-50%) under field evaluation (Daunay *et al*., 1993). Resistance to the herbicide Atrazine has been transferred from the Atrazine-resistant biotype *S. nigrum* into somatic hybrids of egg plant by using chemical (Guri and Sink, 1988b) and electrical (Sihachakr et al., 1989b) procedures of protoplast fusion. All the somatic hybrids had *S. nigrum* ctDNA, conferring resistance to 0.1M Atrazine. Though generally unfeasible by sexual hybridization, intergeneric crosses have been produced in egg palnt via protoplast fusion (Toki et al., 1990; Gurri et al., 1991). Although combination of complete genomes is easily possible, the somatic hybrids being partially or completely sterile, their usefulness in egg plant breeding programmes will be limittd since the

somatic hybrids are amphidiploids in nature, intensive back crossing will be required for transfer desirable traits into the cultivated egg plant. Fertile hybrids with tolerance to Verticillium wilt, and particularly, a morphology close to the cultivated egg plant, were recoverd after asymmetric fusion between egg plant protoplasts and X- rays irradiated protoplasts of *S. torvum* (Jarl et al., 1999). Thus Somatic hybridization can effect in the resistance traits transfer in egg plant. But the success of tetraploids symmetric somatic hybrids in crop improvement programme depends on their ability to be back crossed with their recurrent egg plant geneotype (Collonnier *et al*., 2001).

Embryo rescue

Embryo rescue can also contribute to some extent in overcoming crossability barriers in distant hybridization. This technique was successfully used to recover sexual hybrids of egg plant with *S. khasianum* (Sharma *et al*., 1980), *S. sisymbrifolium* (Sharma *et al*., 1984) and *S. torvum* (Daunay *et al*., 1991; Kumchai et al., 2013). Bletsos et al., 1998 developed hybrids with S. torvum and S. sisymbrifolium through embryo rescue by culturing immature ovule in MS medium. Fertility was restored in hybrids of S. melongena with S. macrocarpon (Gowda et al., 1991) and S. torvum (Daunay et al., 1991), when diploid hybrids (2x) were brought to the amphidiploids status (4x) by colchicines treatment. In order to produce interspecific hybrids between S. melongena and S. indicum, embryo rescue technique was adopted and developing embryos of 15 days old responded better for regeneration at MS basal Medium + 5 ppm BAP+ 30 ppm IAA (Srinivasan et al., 2007). Verba et al., 2010 attempted embryo rescue technique successfully to transfer resistance gene from S. aethiopicum and S. integrifolium to the cultivated S. melongena. Also they have optimized the stage of embryonic development optimal for isolation and the nutrient media composition for embryo development and rooting of seedlings.

Molecular markers

The advent of molecular marker technology has led to the understanding of genetic diversity in various crop species. This technology has been widely used to identify and determine relationships at the species and cultivar levels (Rajaseger et al., 1997; Raina et al., 2001; Martins et al., 2003, Furini and Wunder, 2004). Earlier genetic diversity studies in egg plant were carried out using polymorphic and abundant markers viz., RFLP (Isshiki et al., 1998; Isshiki et al., 2001, Doganlar et al., 2002a) and RAPD markers (Karihaloo et al., 1995; Nunome et al., 2001, Ansari and Singh, 2013). More recently, simple sequence repeats (SSR) or microsatellite markers (Nunome et al., 2003a, b; Stagel et al., 2008; Munoz-Falcon et al., 2008, Nunome et al., 2009, Tumbilen et al., 2009, Demir et al., 2010; Sunseri et al., 2010; Qiu-jin et al., 2010; ge et al., 2011) and amplified fragment length polymorphism (AFLP) markers were developed and used in egg plant diversity assessment. Using SSR markers, Caguit and Hautea, 2014 could clearly differentiate the land races, cultivars and crop wild relatives of egg plant. The crop wild relatives were the most diverse group followed by the land races, while improved cultivars were the least diverse. Genic microsatellites (SSR) markers were identified from an expressed sequence tag library of S. melongena and used for analysis of 47 accessions of egg plant and closely related species (Tumbilen et al., 2011). The markers had very good polymorphism in the 18 species tested including 8 S. melongena accessions.

CONCLUSION

Being the centre of diversity, India has huge variability in egg plant genetic resources. Resistance to most of its biotic and abiotic stresses is present within the available wild gene pool. Since information on status of wild Solanum conservation is scanty, efforts should be made to collect, characterize and conserve the available genetic resources. Conservation of land races showing tolerance to various stresses has gained limited attention. Attempts to improve resistance through introgression of traits from wild relatives have had limited success owing to sexual incompatibilities. Efficient utilization of these genetic resources urges integration of conventional breeding methods with biotechnological techniques for effecting the transfer of beneficial genes (traits) into the cultivated egg plants. Mapping the location of occurrence will be helpful for the future research programs and through genomics and marker assisted studies, genes and mechanisms responsible for resistance to various stresses may be identified which could be useful in the future breeding programs.

REFERENCES

Abdoulaye, S. (1992). Advances in seed research on embryo dormancy in African eggplant (*Solanum aethiopium*, L., spp Kumba). Abstract on XXVIth International Horticultural Congress, Senegal, West Africa, Abstract No. 1620 – 1640).

Ansari, A.M. and Singh, Y.V. (2013). Molecular diversity of brinjal (Solanum melongena L.) genotypes revealed by RAPD marker. J Res (BAU). 25(1):41-8.

Ahmad, Q. (1987). Sources of resistance in brinjal to phomopsis fruit rot. Ind. Phytopathol. 40:98.

Ali, M., Okubo, H. and Fujieda, K. (1992). Production and characterization of Solanum amphidiploids and their resistance to bacterial wilt. Scientia horticulturae. 49(3-4):181-96.

Ali, M. and Fujieda, K. (1990). Cross compatibility between eggplant (Solanum melongena L.) and wild

relatives. Journal of the Japanese Society for Horticultural Science. 58(4):977-84.

Anis, M., Baksh, S. and Iqbal, M. (1994). Cytogenetic Studies on the F1 Hybrid Solanum incanum× S. melongena var. American Wonder. Cytologia. 59(4):433-6.

Anjaneyulu, A. and Ramkrishnan (1968). Reaction of *Solanum species* to little leaf of brinjal. Madras Agricultural Journal. 55: 142-143.

Ano, G., Hebert, Y., Prior, P. and Messiaen, C.M. (1991). A new source of resistance to bacterial wilt of eggplants obtained from a cross: Solanum aethiopicum L× Solanum melongena L. Agronomie. 11(7):555-60.

APEDA, **Agricultural & Processed Food Products Export Development Authority,** (2011). Ministry of Commerce & Industry, Govt. of India, India. Available at: www.apeda.gov.in/

Arora, R.K. and Nayar, E.R. (1984). Wild relatives of crop plant in India. National Bureau of Plant Genetic Resources; New Delhi.

Baksh, S. and Iqbal, M. (1979). Compatibility relationships in some non tuberous species of *Solanum*. Journal of Horticultural Science. 54(2): 163

Behera, T.K. and Singh, N. (2002). Inter-specific crosses between eggplant (Solanum melongena L.) with related Solanum species. Scientia horticulturae. 95(1-2):165-72.

Behera, T.K., Singh, N., Kalda, T.S. and Gupta, S.S. (1999). Screening for shoot and fruit borer incidence in eggplant genotypes under Delhi conditions. Indian Journal of Entomology. 61(4):372-5.

Bhaduri, P.N. (1951). Interrelationship of non-tuberiferous species of Solanum with some consideration of the origin of brinjal (S. melongena L.). Indian. J. Genet. 11:75-82.

Bhatt, D.P. and Fassuliotis, G. (1981). Plant regeneration from mesophyll protoplasts of eggplant. Zeitschrift für Pflanzenphysiologie. 04(1):81-9.

Bindra, O.S. and Mahal, M.S. (1981). Varietal resistance in eggplant (brinjal)(Solanum melongena) to the cotton jassid (Amrasca biguttula biguttula). Phytoparasitica. 9(2):119-31.

Bithell, S.L., McKenzie, B.A., Bourdot, G.W., Hill, G.D. and Wratten, S.D. (2013). *Solanum nigrum* seed primary dormancy status: a comparison of laboratory and field stored. New Zealand Plant Protection. 55:222-227.

Bletsos, F.A., Roupakias, D.G., Tsaktsira, M.L., Scaltsoyjannes, A.B. and Thanassoulopoulos, C.C. (1998). Interspecific hybrids between three eggplant (Solanum melongena L.) cultivars and two wild species (Solanum torvum Sw. and Solanum sisymbriifolium Lam.). Plant Breeding. 117(2):159-64.

Chakrabarti, A.K. and Choudhury, B. (1974). Effect of little leaf disease on the metabolic changes in the susceptible cultivar and resistant allied species of brinjal (Solanum melongena L.). Vegetable Science. 1(1):12-7.

Sekar, K.C. (2012). Invasive alien plants of Indian Himalayan region—diversity and implication. American Journal of Plant Sciences. 3(02):177.

Chelliah, S. and Srinivasan, K. (1983). Resistance in bhindi, brinjal and tomato to major insect and mite pests. InNational Seminar on breeding crop plants for resistance to pests and diseases (pp. 43-44).

Chennaveeraiah, M.S. and Krishnappa, D.G. (1965). The occurrence and behaviour of accessory chromosomes in Solanum species. Nucleus. 8(2):161-70.

Collonnier, C., Fock, I., Kashyap, V., Rotino, G.L., Daunay, M.C., Lian, Y., Mariska, I.K., Rajam, M.V., Servaes, A., Ducreux, G., Sihachakr, D. (2001). Applications of biotechnology in eggplant. Plant Cell, Tissue and Organ Culture. 65(2):91-107.

Tsay, C.Y. and Lin, M.W. (2005). Enhancement of Resistance to Drought and Flooding Stress for Grafted Tomato and Eggplant Seedlings Using Solanum Torvum as the Rootstock. Plant Seedling. 7(4):21-32.

Daunay, M.C. and Lester, R.N. (1988). The usefulness of taxonomy for Solanaceae breeders, with special reference to the genus Solanum and to Solanum melongena L.(eggplant). Capsicum Newsletter. 7:70-9.

Daunay, M.C., Chaput, M.H., Sihachakr, D., Allot, M., Vedel, F. and Ducreux, G. (1993). Production and characterization of fertile somatic hybrids of eggplant (Solanum melongena L.) with Solanum aethiopicum L. Theoretical and Applied Genetics. 85(6-7):841-50.

Daunay, M.C., Lester, R.N., Ano, G. and Les, Aubergines (1999). In: Charrier A, Jacquot M, Hamon S & Nicolas D (eds) L'Amélioration des Plantes Tropicales (pp 83–107). Repères, CIRAD-ORSTOM

Daunay, M.C., Lester, R.N. and Laterrot, H. (1991). The use of wild species for the genetic improvement of Brinjal eggplant (Solanum melongena) and tomato (Lycopersicon esculentum). Solanaceae III: taxonomy, chemistry, evolution. 27:389-413.

Daunay, M.C. and Dalmasso, A. (1985). Multiplication de Meloidogyne javanica, M. incognita et M. arenaria sur divers Solarium. Revue Nematol. 8(1):31-4.

Daunay, M.C., Bletsos, F., Hennart, J.W., Haanstra, J.P.W. and van der Weerden, G.M. (2013). In *Breakthroughs in Genetics and Breeding of Capsicum and Eggplant* (eds Lanteri, S. and Rotino, G. L.), Proceedings of the XV Meeting on Genetics and Breeding of Capsicum and Eggplant, Turin, Italy, 2–4 September 2013, p. 231.

Daunay, M.C., Lester, R.N., Ano, G. and Eggplant (2001). In: Charrier, A., Jacquot, M., Hamon, S.,

Nicolas, D. (Eds.), Tropical Plant Breeding. CIRAD and Science Publishers, Inc., pp. 199–222.

Deb, D.B. (1980). Enumeration, synonymy and distribution of the Solanaceae in India. J. Econ. Taxon. Bot.1:33-54.

Demir, K., Bakir, M., Sarikamis, G. and Acunalp, S. (2010). Genetic diversity of eggplant (Solanum melongena) germplasm from Turkey assessed by SSR and RAPD markers. Genetics and Molecular Research. 9(3):1568-76.

Dhawan, S.C. and Sethi, C.L. (1976). Observations on the pathogenicity of Meloidogyne incognita to egg plant and on relative susceptibility of some varieties to the nematode [India]. Indian Journal of Nematology. 6: 39–46

Doganlar, S., Frary, A., Daunay, M.C., Lester, R.N. and Tanksley, S.D. (2002). A comparative genetic linkage map of eggplant (Solanum melongena) and its implications for genome evolution in the Solanaceae. Genetics. 161(4):1697-711.

Dutta, P., Singha, A.K., Das, P. and Kalita, S. (2011). Management of brinjal fruit and shoot borer, Leucinodes orbanalis Guenee in agro-ecological condition of West Tripura. Scholarly journal of Agricultural Science. 1(2):16-9.

Edmonds, J.M. and Chweya, J.A. (1997). Black nightshades: Solanum nigrum L. and related species. Bioversity International.

Fassuliotis, G. and Dukes, P. (1972). Disease reactions of Solanum melongena to root-knot nematode, Meloidogyne incognita. Plant Disease Reporter, 57, pp.606-608.

Furini, A. and Wunder, J. (2004). Analysis of eggplant (Solanum melongena)-related germplasm: morphological and AFLP data contribute to phylogenetic interpretations and germplasm utilization. Theoretical and Applied Genetics. 108(2):197-208.

Gallagher, R.V., Hughes, L., Leishman, M.R. and Wilson, P.D. (2010). Predicted impact of exotic vines on an endangered ecological community under future climate change. Biological invasions. 12(12):4049-63.

Ge, H., Li, H., Liu, Y., Li, X. and Chen, H. (2011). Characterization of novel developed expressed sequence tag (EST)-derived simple sequence repeat (SSR) markers and their application in diversity analysis of eggplant. African Journal of Biotechnology. 10(45):9023-31.

Gill, H.S., Bhagchandani, P.M. and Thakur, M.R. (1978). Pusa purple cluster-a brinjal with wide adaptability [eggplants, India]. Indian Horticulture. Indian Hort, 23(1):13-16.

Ginoux, G. and Laterrot, H. (1991). Greffage de l'aubergine: reflexions sur le choix du portegreffe. PHM Revue Horticole. 321(1):49-54.

Gleddie, S., Keller, W.A. and Setterfield, G. (1986). Production and characterization of somatic hybrids between Solanum melongena L. and S. sisymbriifolium Lam. Theoretical and applied genetics. 71(4):613-21.

Gopinath, G. and Madalageri, B.B. (1986). Bacterial wilt (Pseudomonas solanacearum EF Smith) resistance in eggplant. Veg. Sci. 13:189-95.

Goth, R.W., Haynes, K.G. and Barksdale, T.H. (1991). Improvement of levels of bacterial wilt resistance in eggplant through breeding. Plant disease. 75:398-401.

Gowda, P.H., Shivashankar, K.T. and Joshi, S.H. (1990). Interspecific hybridization between Solanum melongena and Solanum macrocarpon: study of the F1 hybrid plants. Euphytica. 48(1):59-61.

Guri, A. and Sink, K.C. (1988). Interspecific somatic hybrid plants between eggplant (Solanum melongena) and Solanum torvum. Theoretical and applied genetics. 76(4):490-6.

Guri, A., Dunbar, L.J. and Sink, K.C. (1991). Somatic hybridization between selected Lycopersicon and Solanum species. Plant cell reports. 10(2):76-80.

Hanudin, H., Hanafiah, and Goas, M.A. (1998). Screening of eggplant accessions for resistance to bacterial wilt. In: Hartman GL & Hayward AC (eds) Bacterial wilt, ACIAR Proc 45. pp 191–192. Kaohsiung, Taiwan

Hayati, N.E., Sukprakarn, S. and Juntakool, S. (2005). Seed germination enhancement in Solanum stramonifolium and Solanum torvum. Kasetsart Journal (Natural Science). 39(3):368-76.

Hébert, Y. (1985). Comparative resistance of 9 Solanum species to bacterial wilt (Pseudomonas solanacearum) and to the nematode Meloidogyne incognita. Importance for breeding aubergine (Solanum melongena L.) in a humid tropical zone. Agronomie. 5(1):27-32.

IISG (2008). Global Invasive Species Database. http://www.cabi.org/isc/abstract/20097200468

Isshiki, S., Suzuki, S. and Yamashita, K.I. (2003). RFLP analysis of mitochondrial DNA in eggplant and related Solanum species. Genetic Resources and Crop Evolution. 50(2):133-7.

Isshiki, S., Uchiyama, T., Tashiro, Y. and Miyazaki, S. (1998). RFLP analysis of a PCR amplified region of chloroplast DNA in eggplant and related Solanum species. Euphytica. 102(3):295.

Iwamoto, Y., Hirai, M., Ohmido, N., Fukui, K. and Ezura, H. (2007). Fertile somatic hybrids between Solanum integrifolium and S. sanitwongsei (syn. S. kurzii) as candidates for bacterial wilt-resistant rootstock of eggplant. Plant biotechnology. 24(2):179-84.

Jarl, C.I., Rietveld, E.M., De, Haas. J.M. (1999). Transfer of fungal tolerance through interspecific somatic hybridisation between Solanum melongena and S. torvum. Plant cell reports. 18(9):791-6.

Jia, J.F. and Potrykus, I. (1981). Mesophyll protoplasts from Solanum melongena var depressum bailey regenerate to fertile plants. Plant cell reports. 1(2):71-2.

Joshua, A. (1977). Seed germination of Solanum incanum: an example of germination problems of tropical vegetable crops. In Symposium on Seed Problems in Horticulture. 83 pp. 155-162.

Kaan, F. (1973). Etude de l'heredite de la resistance de l'aubergine (Solanum melogena L.) a l'anthracnose des fruits (Colletotrichum gloeosporioides F. sp. melongenae Penzig Fournet). InAnnales de l'amelioration des plantes.

Kalda, T.S., Swarup, V. and Choudhury, B. (1977). Resistance to Phomopsis blight in eggplant. Veg. Sci. 4(2):90-101.

Karihaloo, J.L., Brauner, S. and Gottlieb, L.D. (1995). Random amplified polymorphic DNA variation in the eggplant, Solanum melongena L.(Solanaceae). Theoretical and Applied Genetics. 90(6):767-70.

Kirti, P.B. and Rao, B.G. (1982). Cytological studies on F 1 hybrids of Solanum integrifolium with S. melongena and S. melongena var. insanum. Genetica. 59(2):127-31.

Knapp, S. (2010). Solanum seaforthianum. PBI Solanum Source: A worldwide treatment. http://www.nhm.ac.uk/research-curation/research/projects/solanaceaesource/

Kulkarni, M., Borse, T. and Chaphalkar, S. (2008). Mining anatomical traits: A novel modelling approach for increased water use efficiency under drought conditions in plants. Czech Journal of Genetics and Plant Breeding-UZPI (Czech Republic).

Kumchai, J., Wei, Y.C., Lee, C.Y., Chen, F.C. and Chin, S.W. (2013). Production of interspecific hybrids between commercial cultivars of the eggplant (Solanum melongena L.) and its wild relative S. torvum. Gen Mol Res. 12(1):755-64.

Pugalendhi, L., Veeraragavathatham, D., Natarjan, S. and Praneetha, S. (2010). Utilizing wild relative ((Solanum viarum) as resistant source to shoot and fruit borer in brinjal (Solanum melongena Linn.). Electronic Journal of Plant Breeding. 1(4):643-8.

Lal, O.P., Sharma, R.K., Verma, T.S., Bhagchandan, P.M. and Chandra, J. (1976). Resistance in Brinjal to shoot and fruit borer (*Leucinodes orbonalis* Guen., *Pyralididae: Lepidoptera*). Veg. Sci. 3: 111–116

Lester, R.N. and Hasan, S.M. (1991). Origin and domestication of the brinjal egg-plant, Solanum melongena, from S. incanum, in Africa and Asia. Hawkes, J, G,, Lester, R, N,, Nee, M,, Estrada, N ed (s). Solanaceae III. Taxonomy, chemistry, evolution.. Roy. Bot. Gard.: Kew & Linnean Soc.: London. 369-87.

Levin, R.A., Myers, N.R. and Bohs, L. (2006). Phylogenetic relationships among the "spiny solanums"(Solanum subgenus Leptostemonum, Solanaceae). American Journal of Botany. 93(1):157-69.

Li, H.P., Goth, R.W. and Barksdale, T.H. (1988). Evaluation of resistance to bacterial wilt in eggplant. Plant disease (USA). 72(5): 437–439

Mabberley, DJ. (2008). Mabberley's plant-book: a portable dictionary of plants, their classifications and uses. Cambridge University Press.

Mall, N.P., Pandey, R.S., Singh, S.V. and Singh, S.K. (1992). Seasonal incidence of insect-pests and estimation of the losses caused by shoot and fruit borer on brinjal. Indian Journal of Entomology. 54(3):241-7.

Mathur, A., Singh, N.P. and Swaroop, S. (2012). Management of brinjal shoot and fruit borer: Dilemma of adopting Bt brinjal over Integrated Pest Management technology. InProceedings of International Conference on Clean and Green Energy, Singapore IPCBEE 27, pp. 93-97.

Mayee, C.D. and Munsi, C.D. (1972). Mycoplasma-a- new threat to vegetables. Punjab Horticulture Journal. 22: 190-193.

McCammon, K.R. (1983). Morphological and cytogenetic analyses of an interspecific hybrid eggplant, Solanum melongena× Solanum torvum. Hort Sci. 18:894-5.

Messiaen, C.M. (1989). L'aubergine. In: Le potager tropical, Cultures spéciales, Vol 2 (399 p) Collection Techniques vivantes, Agence de Coopération Culturelle et Technique - Presses Univ., Paris

Mote, U.N. (1982). Varietal susceptibility of brinjal (Solanum melongena L.) to jassid (Amrasca biguttula biguttula Ishida). Journal of the Maharashtra Agricultural Universities. 7(1):59-60.

Muñoz-Falcón, J.E., Prohens, J., Vilanova, S. and Nuez, F. (2008). Characterization, diversity, and relationships of the Spanish striped (Listada) eggplants: a model for the enhancement and protection of local heirlooms. Euphytica. 164(2):405-19.

Mutegi, E., Snow, A.A., Rajkumar, M., Pasquet, R., Ponniah, H., Daunay, M.C. and Davidar, P. (2015). Genetic diversity and population structure of wild/weedy eggplant (Solanum insanum, Solanaceae) in southern India: Implications for conservation. American Journal of Botany. 102(1):140-8.

Prabhu, M., Natarajan, S., Veeraragavathatham, D. and Pugalendhi, L. (2009). The biochemical basis of shoot and fruit borer resistance in interspecific progenies of brinjal (Solanum melongena). EurAsian Journal of BioSciences.3:50-7.

Nagia, D.K., Malik, F., Kumar, S., Saleem, M.D., Sani, M.L. and Kumar, A. (1993). Studies on control of cotton jassid and leaf blight on brinjal crop. Plant Protection Bulletin Faridabad. 45:16-8.

Nasir, J.Y. (1985). Solanaceae In: Ali SI and Nasir E (eds). Flora of Pakistan, Fascicle 168. Pak. Agric. Research council, Islamabad. p.61.

Nee, M. (1999). Synopsis of Solanum in the new world. Solanaceae IV: advances in biology and

utilization. Kew: The Royal Botanic Gardens, Kew. 285-333.

Nishio, T., Mochizuki, H. and Yamakawa, K. (1984). Interspecific cross of eggplants and related species. Bulletin of the Vegetable and Ornamental Crops Research Station. Series A.(Japan).

Kumar, N.K.K., Nagaraju, D.K., Virakthamath, C.A., Ashokan, R., Ranganath, H.R., Chandrashekhara, K.N., Rebijith, K.B. and Singh, T.H. (2010). Gall insects damaging eggplant and bell peppers in South India, Eds. J. Prohens & A Rodriguez-Burruezo, Advances in Genetics and Breeding of capsicum and eggplant, Editorial de la Universitat Politecnica de Valencia, Spain.

Nothmann, J. and Ben-Yephet, Y. (1979). Screening eggplant and other Solanum species for resistance to Verticillium dahliae [Israel]. Plant Disease Reporter (USA).

Nunome, T., Ishiguro, K., Yoshida, T. and Hirai, M. (2001). Mapping of fruit shape and color development traits in eggplant (Solanum melongena L.) based on RAPD and AFLP markers. Breeding science. 51(1):19-26.

Nunome, T., Negoro, S., Kono, I., Kanamori, H., Miyatake, K., Yamaguchi, H., Ohyama, A. and Fukuoka, H. (2009). Development of SSR markers derived from SSR-enriched genomic library of eggplant (Solanum melongena L.). Theoretical and Applied Genetics. 119(6):1143-53.

Nunome, T., Suwabe, K., Ohyama, A. and Fukuoka, H. (2003). Characterization of trinucleotide microsatellites in eggplant. Breeding science. 53(1):77-83.

Omidiji, M.O. (1981). Cytogenetic studies on the F1 hybrid between the african egg-plant, Solanum gilo raddi, and Solanum melongena L. Horticultural research.

Peter, K.V., Gopalakrishnan, T.R., Rajan, S. and Sadhan Kumar, P.G. (1993). In: Hartman GL & Haywards AC (eds) Bacterial wilt, ACIAR Proc. 45. pp 183–190. Kaohsiung, Taiwan

Pochard, E., Daunay, M.C. (1977). Recherches sur l'aubergine. Rapp. d'act.p.1978.

Preneetha, S. *Breeding for shoot and fruit borer (Leuclnodes orbonalis guenee) resistance in brinjal (Solanum melongena l.)* (Doctoral dissertation, Tamil Nadu Agricultural University).

Srinivasan, R., Venkatesan, M. and Amudha, R. (2007). Studies on wide hybridization between Solanum melongena L. and Solanum indicum L. Agricultural Science Digest.27(2):136-7.

Raj, K.G. and Kumaraswami, T. (1979). Screening of eggplants for resistance to Epilachna vigintioctopuntata. Sci. Cult.45(2):60-1.

Rajasekaran, S. and Sivasubramanian, V. (1971 Jan 1). Cytology of the F 1 hybrid of Solanum zuccagnianum Dun.× S. melongena L. Theoretical and Applied Genetics.41(2):85-6.

Rajasekaran, S. *Cytogenetic studies on sterility in certain inter-specific hybrids of Solanum* (Doctoral dissertation, Ph. D. Thesis).

Rajasekaran, S. (1971 Jan 1). Cytological Studies on the F1 Hybrid (Solanum Xanthocarpum Schrad. and Wendl. X S. Melongena L.) and its Amphidiploid. Caryologia.24(3):261-7.

Rangaswamy, P. and Kadambavanasundaram, M. (1973). study on the inheritance of certain qualitative characters in the cross between Solanum indicum L. and Solanum melongena L. South Indian horticulture.

Rao, G.R. and Baksh, S. (1981). Relationship between Solanum melongena L. and Solanum integrifolium Poir. Indian Journal of Genetics and Plant Breeding (The).41(1):46-53.

Rao, G.R. (1980 Jan 1) Cytogenetic Relationship and Barriers to Gene Exchange between Solanum Melongena L. and Solanum Hispidum Pers. Caryologia.33(3):429-33.

Rao, N.N. (1979). The barriers to hybridisation between *Solanum melongena* and some other species of *Solanum*. In: Hawkes JG, Lester RN & Skelding AD (eds) The Biology and Taxonomy of the Solanaceae. (pp 605–614). Acad. Press, London

Rao, S.V. and Rao, B.G. (1984 Mar 1) Studies on the crossability relationships of some spinous Solanums. Theoretical and applied genetics.67(5):419-26.

Rotino, G.L., Perri, E., Acciarri, N., Sunseri, F. and Arpaia, S. (1997 Jan 1) Development of eggplant varietal resistance to insects and diseases via plant breeding. Advances in Horticultural Science.193-201.

Sambandam, C.N. and Chelliah, S. (1983/05/25–27) Breeding brinjal for resistance to *Aphis gossipii*. C.R. National seminar on breeding crop plants for resistance to pests and diseases.(p 15) Coimbatore, Tamil Nadu, India

Sambandam, C.N., Natarajan, K. and Chelliah, S. (1976). Studies on the inheritance of resistance in eggplants and certain wild Solanum spp. against Epilachna vigintioctopunctata F by hybridization and grafting technique [India]. Auara..

Samuels, J. (2–4 September 2013) In *Breakthroughs in Genetics and Breeding of Capsicum and Eggplant* (eds Lanteri, S. and Rotino, G. L.), Proceedings of the XV Meeting on Genetics and Breeding of Capsicum and Eggplant, Turin, Italy. pp. 253–261

Sarvayya, J. (1936). The first generation of an interspecific cross in Solanums, between Solanum melongena and S. xanthocarpum. Madras Agr. J.24:139-42.

Schaff, D.A., Jelenkovic, G., Boyer, C.D. and Pollack, B.L. (1982). Hybridization and fertility of hybrid derivatives of Solatium melongena L. and Solanum macrocarpon L. Theoretical and Applied Genetics.62(2):149-53.

Schalk, J.M., Stoner, A.K., Webb, R.E. and Winters, H.F. (1975). Resistance in eggplant,

Solanum melongena L., and nuntuber-bearing Solanum species to carmine spider mite. Journal-American Society for Horticultural Science (USA).

Sharma, D.R. (1984). Crossability and pollination in some non-tuberous Solanum species. Ind J Agric Sci.54:514-7.

Sheela, K.B. (1984). Resistance to bacterial wilt in a set of eggplant breeding lines. Ind J Agric Sci.54:457-60.

Slddiqui, B.A. and Khan, I.A. (1979). Interrelationship Between A Interspecific Hybrid of Solanum Incanum L. and Solanum Melongena L. Var. Giant of Banaras. Indian Journal of Horticulture.36(4):438-42.

Sihachakr, D., Chaput, M.H., Serraf, I. and Ducreux, G. (1993). Regeneration of plants from protoplasts of eggplant (Solanum melongena L.). InPlant Protoplasts and Genetic Engineering IV. (pp. 108-122). Springer, Berlin, Heidelberg.

Sihachakr, D., Daunay, M.C., Serraf, I., Chaput, M.H., Mussio, I., Haicour, R., Rossignol, L. and Ducreux, G. (1994). Somatic hybridization of eggplant (Solanum melongena L.) with its close and wild relatives. InSomatic Hybridization in Crop Improvement I (pp. 255-278). Springer, Berlin, Heidelberg.

Sihachakr, D., Haicour, R., Chaput, M.H., Barrientos, E., Ducreux, G. and Rossignol, L. (1989). Somatic hybrid plants produced by electrofusion between *Solanum melongena* L. and *Solanum torvum*Sw. Theor Appl Genet.77:1–6

Singh, H. and Indegenous plant wealth of vegetable crops. (1972). Paper presented at Summer institute of vegetable seed production. Ludhiana.

Sitaramaiah, K., Sinha, S.K. and Vishwakarma, S.N. (1985). Reaction of brinjal cultivars to bacterial wilt caused by Pseudomonas solanacearum. Indian J Mycol Plant Pathol.14:218-22.

Sonawane, M.L. and Darekar, K.S. (1984). Reaction of eggplant cultivars and Solanum species to Meloidogyne incognita. Nematologia Mediterranea.12(1).

Srinivasan, R. (2009). Insect and mite pests on eggplant. AVRDC-WorldVegetableCenter.

Srinivasan, R. (2008) Integrated Pest Management for eggplant fruit and shoot borer (Leucinodes orbonalis) in south and southeast Asia: Past, Present and Future. Journal of Biopesticides.1(2):105-12.

Stàgel, A., Portis, E., Toppino, L., Rotino, G.L. and Lanteri, S. (2008). Gene-based microsatellite development for mapping and phylogeny studies in eggplant. BMC genomics.9(1):357.

Stattmann, M., Gerick, E. and Wenzel, G. (1994 Jan 1). Interspecific somatic hybrids between Solanum khasianum and S. aculeatissimum produced by electrofusion. Plant cell reports.13(3-4):193-6.

Sugha, S.K., Kumar, S. and Pathania, N.K. (2002). Evaluation of brinjal germplasm against Phomopsis disease. Capsicum Eggplant Newsletter. 21. Total de registros: 1 BD FAUSAC Ayuda MegaBase Agropecuaria Alianza SIDALC.

Sunseri, F., Polignano, G.B., Alba, V., Lotti, C., Bisignano, V., Mennella, G., Drsquo, A., Bacchi, M., Riccardi, P., Fiore, M.C. and Ricciardi, L. (2010). Genetic diversity and characterization of African eggplant germplasm collection. African Journal of Plant Science.4(7):231-41.

Swaminathan, M.S. (1949). Cytotaxonomic studies in the genus Solanum. Unpublished thesis (submitted to IARI, New Delhi).

Tachibana, S., Eggplant. In: Konishi, K., Iwahori, S., Kitagawa, H. and Yakuwa, T. (Eds.) (1994). Horticulture in Japan. Asakura Publishing, Tokyo,. pp. 63–66.

Tamura, N., Murata, Y. and Mukaihara, T. (2002 Nov 1). A somatic hybrid between Solanum integrifolium and Solanum violaceum that is resistant to bacterial wilt caused by Ralstonia solanacearum. Plant cell reports.21(4):353-8.

Telek, L., Delpin, H. and Cabanillas, E. (1977 Apr 1). Solanum mammosum as a source of solasodine in the lowland tropics. Economic Botany.31(2):120-8.

Tewari, G.C., Moorthy, P.N. and Sardana, H.R. (1987 Oct 1). Nature of damage and chemical control of gallmidge, asphondylia sp infesting eggplant. Indian journal of agricultural sciences.57(10):745-8.

Toki, S., Kameya, T. and Abe, T. (1990 Nov 1). Production of a triple mutant, chlorophyll-deficient, streptomycin-, and kanamycin-resistant Nicotiana tabacum, and its use in intergeneric somatic hybrid formation with Solanum melongena. Theoretical and applied genetics.80(5):588-92.

Topino, L., Acciari, N., Mennella, G., Lo Scalzo, R. and Rotino, G.L. (2009 Sep.). Introgression breeding of eggplant (Solanum mel ongena L.) by combining biotechnological and conven tional approaches. InProceedings of the 53rd Italian Society of Agricultural Genetics Annual Congress Torino, Italy (Vol. 16, p. 19).

Tümbilen, Y., Frary, A., Daunay, M.C. and Doğanlar, S. (2011 Mar 21). Application of EST-SSRs to examine genetic diversity in eggplant and its close relatives. Turkish Journal of Biology.35(2):125-36.

USDA-ARS. (2014). Germplasm Resources Information Network (GRIN). Online Database. Beltsville, Maryland, USA: National Germplasm Resources Laboratory. http://www.ars-grin.gov/cgi-bin/npgs/html/tax_search.pl

USDA-NRCS. (2014). The PLANTS Database. Baton Rouge, USA: National Plant Data Center. http://plants.usda.gov/

Verba, V.M., Mamedov, M.I., Pyshnaya, O.N., Suprunova, T.N., Shmykova and N.A. (2010). Isolation of eggplant interspecific hybrids by the method of embryo culture. Сельскохозяйственная биология. (5 (eng).

Vanitha, S.M., Chaurasia, S.N., Singh, P.M. and Naik, P.S. (2013). Vegetable statistics. Technical Bulletin.51.

Vavilov, NI. (1951). The origin, variation, immunity and breeding of cultivated plants. LWW; Chron Bot.13 : 1 -364.

Wagner, W.L., Herbst, D.R. and Sohmer, S.H. (1999). Manual of the Flowering Plants of Hawai'i, Vols. 1 and 2. University of Hawai'i and Bishop Museum Press;

Yamaguchi, H., Fukuoka, H., Arao, T., Ohyama, A., Nunome, T., Miyatake, K. and Negoro, S. (2009 Oct 16). Gene expression analysis in cadmium-stressed roots of a low cadmium-accumulating solanaceous plant, Solanum torvum. Journal of Experimental Botany.61(2):423-37.

Yamakawa, K. and Mochizuki, H. (1979). Nature and inheritance of Fusarium-wilt resistance in eggplant cultivars and related wild Solanum species. Yasai Shikenjo hokoku.= Bulletin of the Vegetable and Ornamental Crops Research Station. Series A.

Yaşar, F. and Ellialtioğlu, Ş. (2008). Tuz Stresi Altında Yetiştirilen Patlıcan Genotiplerinde Meydana Gelen Morfolojik, Fizyolojik ve Biyokimyasal Değişimler. Yüzüncü Yıl Üniversitesi. Fen Bilimleri Enstitüsü Dergisi.13(1):51-68.

Zeven, A.C. and Zhukovsky, P.M. (1975). Dictionary of cultivated plants and their centers of diversity. Wageningen: Center for Agricultural Publishing and Documentation.

RESEARCH ARTICLE

FUELWOOD AND FODDER CONSUMPTION FROM AGROFORESTRY AT DIFFERENT ALTITUDINAL ZONES OF GARHWAL HIMALAYA

Bhuvnesh Nagar*, Munesh Kumar[1], Rajiv Pandey[2] and Sushma Rawat

[1]HNB Garhwal University, Srinagar-Garhwal, Uttarakhand 246 174, India
[2]Forest Informatics Division, Forest Research Institute, Dehradun, Uttarakhand 248 006, India
Email: bhuwi@hotmail.com

Received-01.12.2018, Revised-21.12.2018

Abstract: In Himalayan region, agroforestry is one of the strategies for adaptation to climate change through provision of direct and indirect impact on improving the livelihood of the farmers in the form of productive and protective benefits, respectively. The present study attempts to assess the contribution of agroforestry in fuelwood and fodder consumption at different altitudes of Garhwal Himalayan region. Multistage random sampling method was used for the selection of the agroforestry dominated villages during 2015 to 2017. Fuelwood and fodder consumption by households was estimated in regular interval for a period of 24 hrs using weight survey method. The results revealed that fuelwood consumption from agroforestry was 0.44, 0.63, 0.68 and 0.50 kg/capita/day while the consumption from other sources was estimated at 0.84, 0.90, 0.92 and 1.47 kg/capita/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively. Similarly, fodder consumption from agroforestry was estimated at 4.70, 5.35, 5.57 and 3.64 kg/ACU/day while the consumption from other sources was 7.16, 6.98, 7.02 and 10.05 kg/ACU/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitudes, respectively. The estimated results of the study will be helpful in quantifying the contribution of agroforestry in fulfilling the requirements of fuelwood and fodder. Further the share of agroforestry might assist in framing the policies with respect to the agroforestry adoption as a mechanism for climate change adaptation through the means of protective and productive services as well as by reducing the anthropogenic pressure on forests at higher altitudes.

Keywords: Agroforestry, Biomass, Energy, Fodder, Fuelwood, Garhwal Himalaya

INTRODUCTION

Biomass is one of the principle component of domestic energy source in developing countries (Pandey, 2002). In India, it comprises 75% of the total energy consumption depending upon social and geographical conditions of the region (Khuman et al., 2011). In the Himalayan region, fuelwood is the most important livelihood resources besides the fodder for livestock (Ramakrishnan, 2005). Almost 90% of their energy demand is met from biomass (Sharma et al., 1999) derived from forest (Singh and Sundriyal, 2009), trees growing on homesteads, agricultural lands and common lands outside forests (Pandey, 2002).

Terraced based agriculture field for raising crops with trees is the permanent characteristic of hill farming system (Semwal and Maikhuri, 1996; Maikhuri et al., 1996; Bhatt and Todaria, 1999) alongwith livestock rearing for their basic daily needs (Bhatt, 2002). The rainfed hill agriculture is associated with forestry sector through agroforestry practices (Semwal and Maikhuri, 1996; Kumar et al., 2009) which is closely linked with domestic energy through providing energy in the form of non-conventional energy such as fuelwood and fodder from trees, crop residues, bio-sticks and cow dung (Ravindranath et al., 2005).

In the Garhwal Himalaya, rural households are mainly depend on the forest to meet their energy needs to sustain their livelihood due to remoteness, unemployment and low agricultural productivity (Bhatt and Sachan, 2004; Sharma et al., 2009; Singh and Sundriyal, 2009; Singh et al., 2010; Malik et al., 2014) and had the privileges to collect fuelwood and fodder in limited quantity from forested areas (Rawat et al., 2009). In recent decade the increased dependency of the growing population on finite resources has lead to severe depletion of natural resources especially forests (Duke, 1984; Tucker, 1987; Schickhoff, 1995; Ali and Benjamisen, 2004; Kumar et al., 2009; Malik et al., 2014). In this regard, the government of India (GOI) has initiated new environmental law to restricted biomass collection (Negi and Todaria, 1993; Rawat et al., 2009). Therefore the present study attempts to quantify the contribution of agroforestry to meet the domestic energy needs with the hypothesis that agroforestry contributes in fulfilling the fuelwood and fodder consumption requirements of rural households. The aim of the present study was to estimate the biomass consumption from agroforestry by rural households at different altitudinal zones of Garhwal Himalaya.

MATERIALS AND METHODS

Study area

The study area lies in Garhwal Himalaya between the coordinates 29˚26'-31˚28'N and 77˚49'-80˚06'E ranging from 250 to 7800 m amsl. To understand the altitudinal effect for the contribution of agroforestry for biomass consumption, the study area based on climatic conditions was classified into four altitudinal zones. The area is affected by tropical climate below 800 m, sub-tropical climate between

*Corresponding Author

801–1200 m, sub-temperate between 1201-1600 m and temperate climate above 1600 m (Bagwari and Todaria, 2011). Rainfed agriculture at small terrace is being practiced by the farmers (Rawat et al., 2018). The climate of the region is tropical to temperate, with the winter temperature ranging from 5˚C to 25˚C and from 18˚C and 30˚C during summer season having an annual precipitation of 1476 mm (IMD, 2017).

Data collection

Fuelwood and fodder consumption data was collected from 401 randomly surveyed agroforestry farmers in between 2015-2017 using the multistage random sampling. Two districts namely Pauri Garhwal and Rudraprayag representing the classified altitudinal zones were randomly selected in the first stage followed by selection of agroforestry dominated villages in second stage, and in the last stage, agroforestry practicing households was randomly selected as a primary sampling unit. The villagers depend on agroforestry and on other sources such as village forest, grassland and wasteland for fuelwood and fodder.

Estimation of fuelwood and fodder consumption

Fuelwood and fodder consumption estimation was done through, weight survey method. At first, a wood bundel and grass bundel was weighed and the sampled household was asked to make use of fuelwood and fodder only from the given bundles. Then the left over amount of fuelwood and fodder was deducted from the original weight after a period of 24 hours in order to get the actual per day consumption of each sampled household. For the estimation of fuelwood the procedure given by Mitchell (1979) was used. The following equation was used for fuelwood estimation:

$$Fu_{PCon} = \frac{TFu_{con}}{TH_m}$$

Where, Fu_{PCon} is fuelwood consumption per day by a member of household, TFu_{con} is total fuelwood consumption by a household and TH_m is the total number of members in a household.

Per day fodder consumption by an adult cattle unit (ACU) was estimated by converting the livestock into adult cattle unit and then dividing overall fodder consumption by total number of ACU. For estimation of fodder consumption following equation was used:

$$Fo_{con} = \frac{TFo_{con}}{T_{ACU}}$$

Where, Fo_{con} is per day fodder consumption by an ACU, TFo_{con} is total fodder consumption by a household, and T_{ACU} is total number of ACU in a household.

The ACU values was estimated as per the following details i.e., 1 buffalo = 1.50 ACU (GBPIEHD, 1980; Pandey, 2011a), 1 ox = 1.15 ACU, 1 cow = 1 ACU, young stock of buffalo/cow = 0.75 ACU, for sheep or goat = 0.15 ACU (Yang, 1971).

RESULTS AND DISCUSSION

Fuelwood consumption pattern

Fuelwood consumption from agroforestry and other sources were assessed at different altitudinal zones of Garhwal Himalaya. The statistical significant difference among the fuelwood consumption from different sources i.e., agroforestry and forests was assessed using paired t-test. The results of analysis show that fuelwood consumption from agroforestry and forests differs significantly in all the altitudes (Table 1).

The results of the study revealed that total fuelwood consumption was 1.29, 1.53, 1.61 and 1.98 kg/capita/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively. The result estimates showed that fuelwood consumption increased from lower altitude to higher altitude ranged from 1.29 to 1.98 kg/capita/day with the mean value of 1.60 kg/capita/day (Table 1). The lowest consumption was recorded at <800 m altitude because the people living in lower altitude are easily accessible to alternative commercial sources of cooking energy such as liquid petroleum gas (LPG) and kerosene as compared to higher altitude as well as temperature decreases with increasing altitude, hence the consumption of fuelwood increases with altitude.

The contribution of agroforestry was 0.44, 0.63, 0.68 and 0.50 kg/capita/day while the consumption from other sources was estimated to be 0.84, 0.90, 0.92 and 1.47 kg/capita/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively (Table 1). Fuelwood consumption from agroforestry was recorded to increase from lower to higher with maximum at 1201-1600 m altitude and lowest at the peak (i.e. above 1600 m) while the consumption from other sources increased with altitude because of easily availability of fuelwood from nearby forest and spend less time for collection of fuelwood as compared to lower altitudes.

The altitude influence the availability of commercial energy sources and the climatic conditions as temperature decreases with increasing altitude (Chettri et al., 2002; Sharma et al., 2009) hence people's dependency on wood for energy increases with increasing altitude particularly for space heating, boiling water for them as well as for their livestock and lighting purpose in addition to cooking (Bhatt and Sachan, 2004). The fuelwood consumption in the present study was consistent with the studies reported from Garhwal Himalaya (1.07 to 2.80 kg/capita/day) by Bhatt and Sachan (2004), 1.63 to 2.52 kg/capita/day by Kumar and Sharma (2009) and 1.53 to 2.91 kg/capita/day by Rawat et al. (2018). In other studies authors have reported that fuelwood consumption is greatly influenced by altitude which ranges from 1.61 to 3.24 kg/capita/day in Kedarnath Wildlife Sanctuary (Malik et al., 2014), 1.67 to 2.27 kg/capita/day in Rawanganga micro-watershed (Bagwari and Todaria, 2011), 1.77 to 3.0

kg/capita/day in Takoligad watershed (Dhanai et al., 2014). However, an average fuelwood consumption of 1.49 kg/capita/day has been recorded by Bhatt et al. (1994) for the rural and tribal communities of Western Himalaya.

The results of fuelwood consumption at household level was recorded 5.32, 5.66, 6.72 and 9.98 kg/household/day with an average value of 6.72 kg/household/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively. Fuelwood consumption from agroforestry at household level was estimated 1.86, 2.41, 2.60 and 2.54 kg/household/day with an average value of 2.35 kg/household/day and from other sources was 3.46, 3.20, 3.50 and 7.44 kg/household/day with an average value of 4.37 kg/household/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively (Table 1). Various researchers have reported that at household level fuelwood consumption mainly depends on the size of the family (Bhatt and Sachan, 2004; Kumar and Sharma, 2009; Sharma et al., 2009; Bagwari and Todaria, 2011; Malik et al., 2014) which was observed highest at the peak (i.e. >1600 m) in the present study followed by 801-1200 m, 1201-1600 m and least recorded at lower altitude (<800 m).

Table 1. Fuelwood consumption (Mean ± SD) from different sources at four altitudinal zones of Garhwal Himalaya

Source	Altitudinal zones				
	<800 m (n=101)	**801-1200 m (n=100)**	**1201-1600 m (n=104)**	**>1600 m (n=96)**	**Mean**
Fuelwood (kg/capita/day)					
Agroforestry	0.44 ± 0.15	0.63 ± 0.25	0.68 ± 0.25	0.50 ± 0.16	0.57 ± 0.23
Forest	0.84 ± 0.33	0.90 ± 0.36	0.92 ± 0.31	1.47 ± 0.32	1.03 ± 0.42
Total	1.29 ± 0.39	1.53 ± 0.44	1.61 ± 0.40	1.98 ± 0.35	1.60 ± 0.47
t-test (p-value)	-11.733 (<0.05)	-5.836 (<0.05)	-6.144 (<0.05)	-26.128 (<0.05)	-18.921 (<0.05)
Fuelwood (kg/household/day)					
Agroforestry	1.86 ± 0.68	2.41 ± 1.06	2.60 ± 0.98	2.54 ± 0.96	2.35 ± 0.97
Forest	3.46 ± 0.98	3.25 ± 0.95	3.50 ± 1.26	7.44 ± 2.00	4.37 ± 2.19
Total	5.32 ± 1.29	5.66 ± 1.51	6.72 ± 1.74	9.98 ± 2.51	6.72 ± 2.59
t-test (p-value)	-14.631 (<0.05)	-6.239 (<0.05)	-6.424 (<0.05)	-25.630 (<0.05)	-18.396 (<0.05)

n is the number of households

The results of the present study revealed that consumption of fuelwood per capita was inversely related to the number of individuals in the family in all the altitudes concluding that family size influences levels of per capita fuelwood consumption, that is, per capita consumption decreases as the family size increases. Linear regression analysis for altitude <800 shows that family size explained 57% (R^2 = 0.5698, n=101) of the fuelwood consumption and with an increase of one family member the daily per capita fuelwood consumption decreased by 0.18 kg. Regression analysis for altitude 801-1200 m shows that family size explained 56% (R^2 = 0.5622, n=100) of the fuelwood consumption and with an increase of one member in the family the daily per capita fuelwood consumption decreased by 0.21 kg. At altitude 1201-1600 m regression analysis shows that family size explained 52% (R^2 = 0.5219, n=104) of the fuelwood consumption and with an increase of one family member the daily per capita fuelwood consumption decreased by 0.18 kg. At altitude >1600 m linear regression analysis shows that family size explained 37% (R^2 = 0.3661, n=96) of the fuelwood consumption and with an increase of one family member the daily per capita fuelwood consumption decreased by 0.12 kg. Thus, the relationship between family size and fuelwood consumption showed a decreasing trend of fuelwood consumption with increased family size. A part from linear regression boxplot was also used to show the variation in the family wise consumption of fuelwood at different altitudes (Fig. 1, Fig. 2, Fig. 3 and Fig. 4).

Similar observations have also been reported by Mahato (2017) in a study of Garhwal Himalayas reporting that with increase in family size, per capita fuelwood consumption decreases. Asik and Masakazu (2017) in their study from Southern Bangladesh have also reported that the fuelwood consumption per capita decreases with the increase in the members of a family.

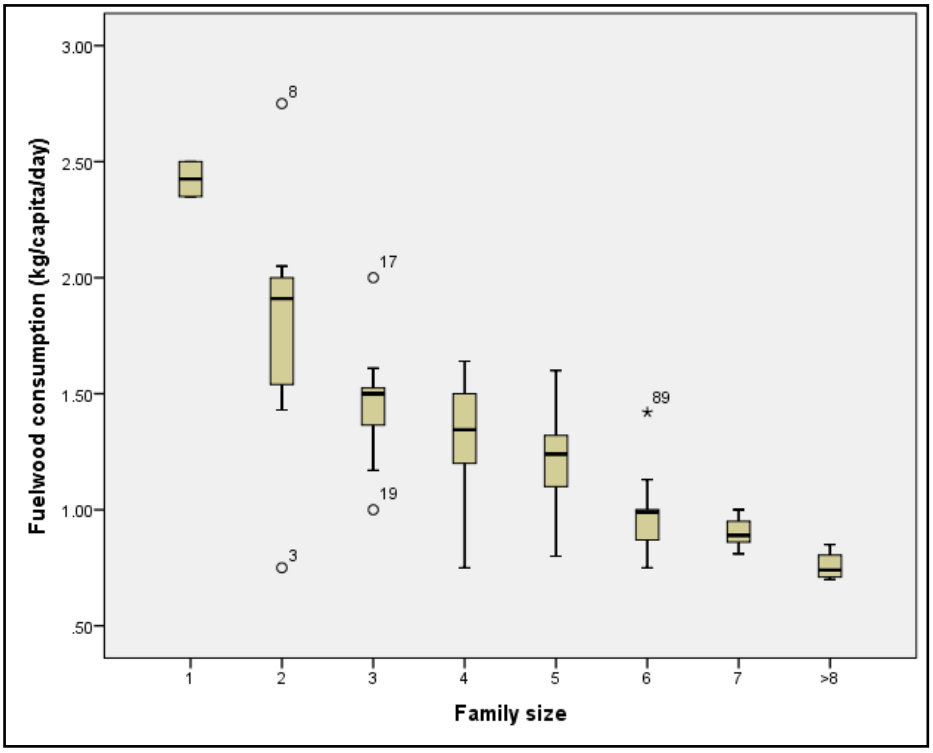


Fig. 2. Box plot showing variation in per capita fuelwood consumption among different family size at altitude <800 m

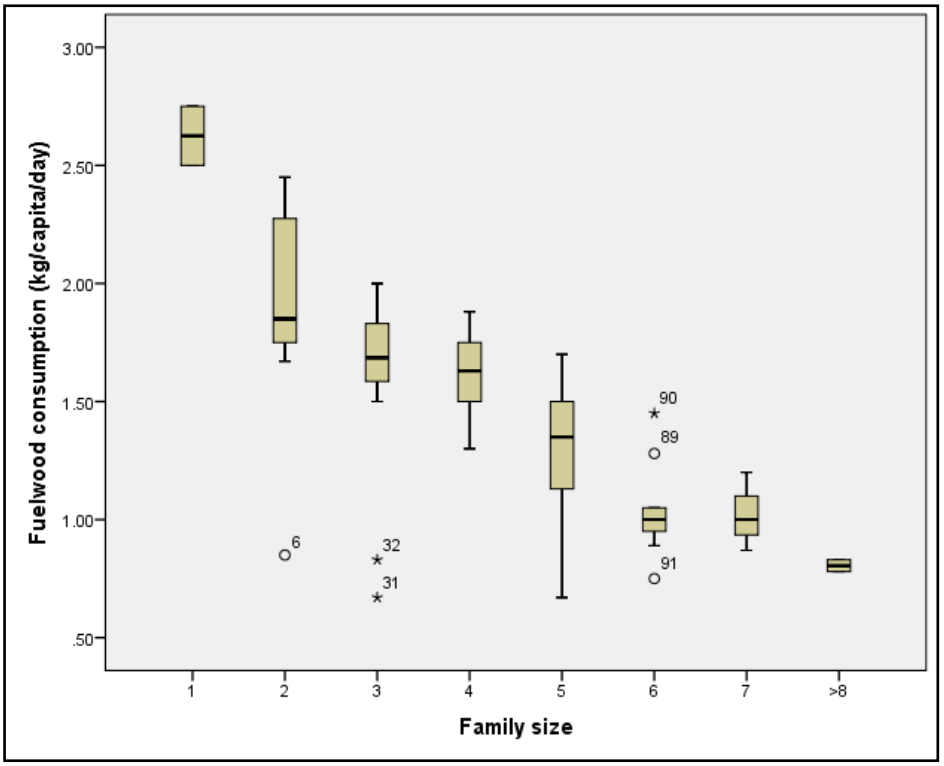


Fig. 3. Box plot showing variation in per capita fuelwood consumption among different family size at altitude 801-1200 m

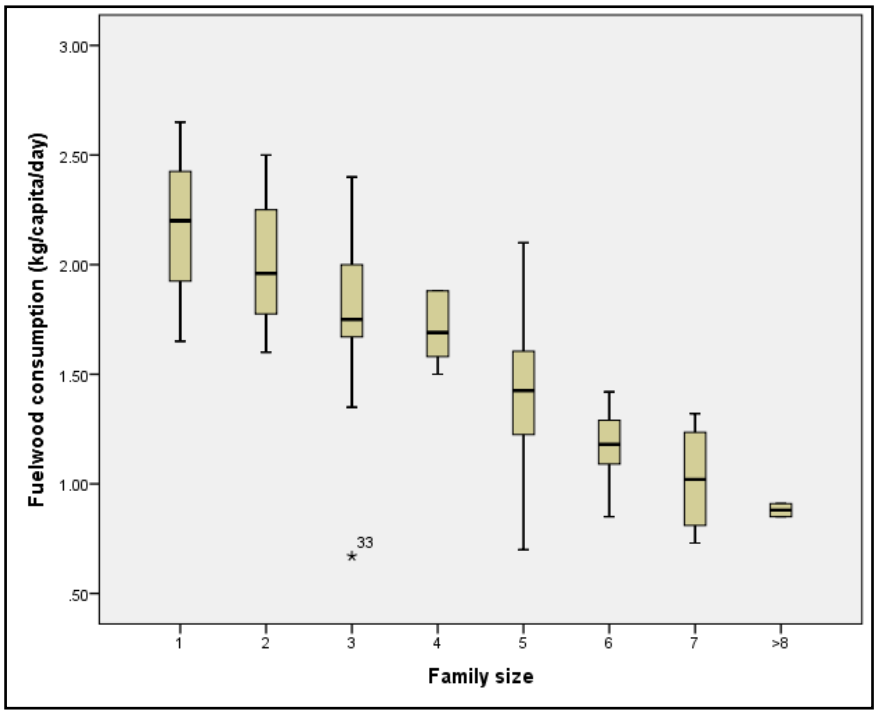


Fig. 4. Box plot showing variation in per capita fuelwood consumption among different family size at altitude 1201-1600 m

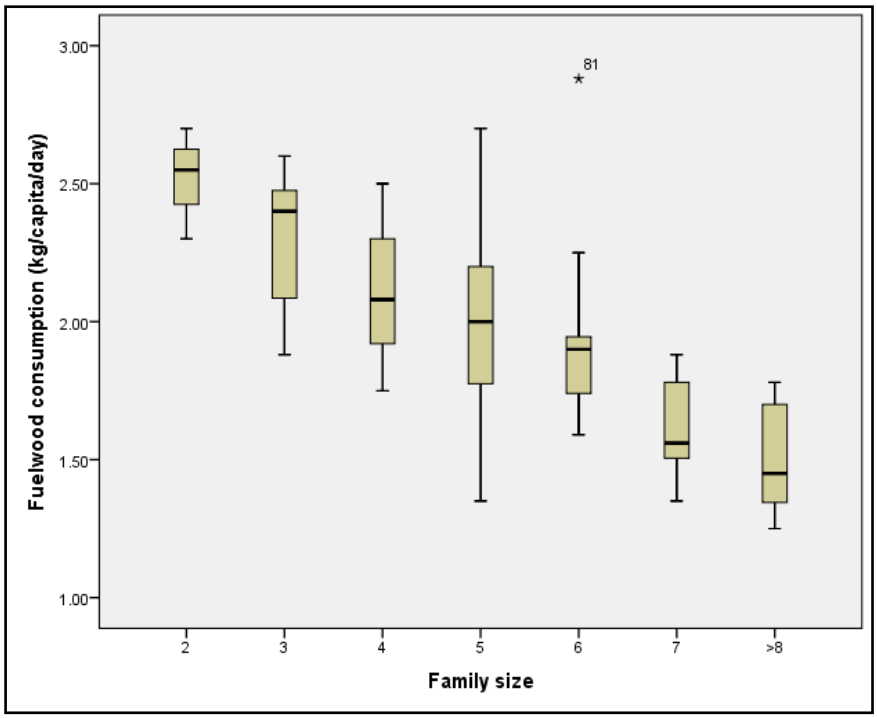


Fig. 5. Box plot showing variation in per capita per day fuelwood consumption among different family size at altitude >1600 m

Fodder consumption pattern

Livelihood of Himalayan people is depended on the terraced based agriculture and rearing livestock simultaneously for fulfilling their daily needs and income saving through the means of reducing expenditure on milk products as well as sometimes for income generation through selling milk and meat as pointed out by farmers during the survey. In the study area various sources of livestock feed were agroforestry and others sources such as forest, grassland and wasteland as pointed out by farmers and has also been reported by Bagwari and Todaria (2011). Therefore, fodder consumption per adult cattle unit (ACU) as well as at household level was

assessed to estimate agroforestry contribution at different altitudes.

Fodder consumption from different sources i.e., agroforestry and forests at different altitudes was statistical tested using paired t-test. The results of analysis show that fodder consumption from agroforestry and forests differs significantly in all the altitudes. The results of the study revealed that overall fodder consumption ranged from 11.86 to 13.69 kg/ACU/day with an average value of 12.60 kg/ACU/day. The estimates of fodder consumption from agroforestry was 4.70, 5.35, 5.57 and 3.64 kg/ACU/day while the consumption from other sources was 7.16, 6.98, 7.02 and 10.05 kg/ACU/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively (Table 2). The contribution of agroforestry in fodder consumption increased with altitude with maximum at 1201-1600 m altitude and afterwards decreases (i.e., above 1600 m). The contribution of agroforestry was lowest at peak because of less adoption and number of trees at agroforestry fields while consumption from other source was directly dependent on the availability of more number of trees on agroforestry farm at 1201-1600 m followed by 801-1200 m altitude.

In various studies from different altitudinal zones of Garhwal Himalaya similar estimates have also been reported for fodder consumption ranging in between 16.65 and 21.77 kg/animal/day (Dhanai et al., 2014) and 15.48 to 15.78 kg/ACU/day (Rawat et al., 2018). Similarly, Pandey (2011b) has also reported that fodder consumed ranges from 9.85 to 14.70 kg/ACU/day, with an average of 13 kg/ACU/day in the lower Himalaya region. The estimates of fodder consumption in the present study are inconsistent with the findings of Bagwari and Todaria (2011). Increased stall feeding by surveyed farmers may be the reason for variation in fodder consumption at high altitude because of the implementation of new government policy for limited livestock grazing in forest to enhance the regeneration.

The overall fodder consumption at household level was reported that 32.99, 33.51, 36.47 and 45.00 kg/household/day with an average value of 36.90 kg/household/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively. Contribution of agroforestry for fodder consumption at household level was 12.75, 14.72, 16.73 and 12.19 kg/household/day while from other sources was 20.23, 18.79, 19.74 and 32.82 kg/household/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively (Table 2). The number of adult cattle unit (ACU) varies among different altitude and is influencing the fodder consumption at household level.

Table 2. Fodder consumption (Mean ± SD) from different sources at four altitudinal zones of Garhwal Himalaya

Source	Altitudinal zone				
	<800 m (n=101)	**801-1200 m (n=100)**	**1201-1600 m (n=104)**	**>1600 m (n=96)**	**Mean**
Fodder (kg/ACU/day)					
Agroforestry	4.70 ± 1.63	5.35 ± 2.06	5.57 ± 1.87	3.64 ± 1.29	4.83 ± 1.89
Forest	7.16 ± 1.70	6.98 ± 2.55	7.02 ± 2.60	10.05 ± 2.67	7.77 ± 2.72
Total	11.86 ± 2.33	12.33 ± 4.04	12.59 ± 3.79	13.69 ± 2.98	12.60 ± 3.42
t-test (p-value)	-10.369 (<0.05)	-7.155 (<0.05)	-5.954 (<0.05)	-21.348 (<0.05)	-18.327 (<0.05)
Fodder (kg/household/day)					
Agroforestry	12.75 ± 5.80	14.72 ± 6.74	16.73 ± 9.75	12.19 ± 6.37	14.14 ± 7.55
Forest	20.23 ± 10.17	18.79 ± 7.20	19.74 ± 8.15	32.82 ± 13.35	22.76 ± 11.41
Total	32.99 ± 14.05	33.51 ± 12.54	36.47 ± 15.69	45.00 ±17.82	36.90 ± 15.80
t-test (p-value)	-8.584 (<0.05)	-6.653 (<0.05)	-3.494 (<0.05)	-18.457 (<0.05)	-15.430 (<0.05)

n is the number of households

In the present study results of linear regression analysis shows that per capita fodder consumption in a household was inversely related to the number of total ACU in the family at all the altitudes concluding that number of ACU influences fodder consumption in a household. Fig. 5 shows total ACU explained 71% (R^2=0.7121, n=101) of the fodder consumption and with an increase of one ACU the daily fodder consumption per ACU decrease by 0.83 kg. Fig. 6 shows total adult cattle unit explained 84%

(R^2 = 0.8425, n=100) of the fodder consumption and with an increase of one ACU the daily fodder consumption per ACU decrease by 1.86 kg. Fig. 7 shows total ACU explained 78% (R^2 = 0.7784, n=104) of the fodder consumption and with an increase of one ACU daily per ACU fodder consumption decrease by 1.24 kg. Fig. 8 shows total adult cattle unit explained 66% (R^2 = 0.6574, n=96) of the fodder consumption and with an increase of one ACU the daily per ACU fodder consumption decrease by 1.05 kg.

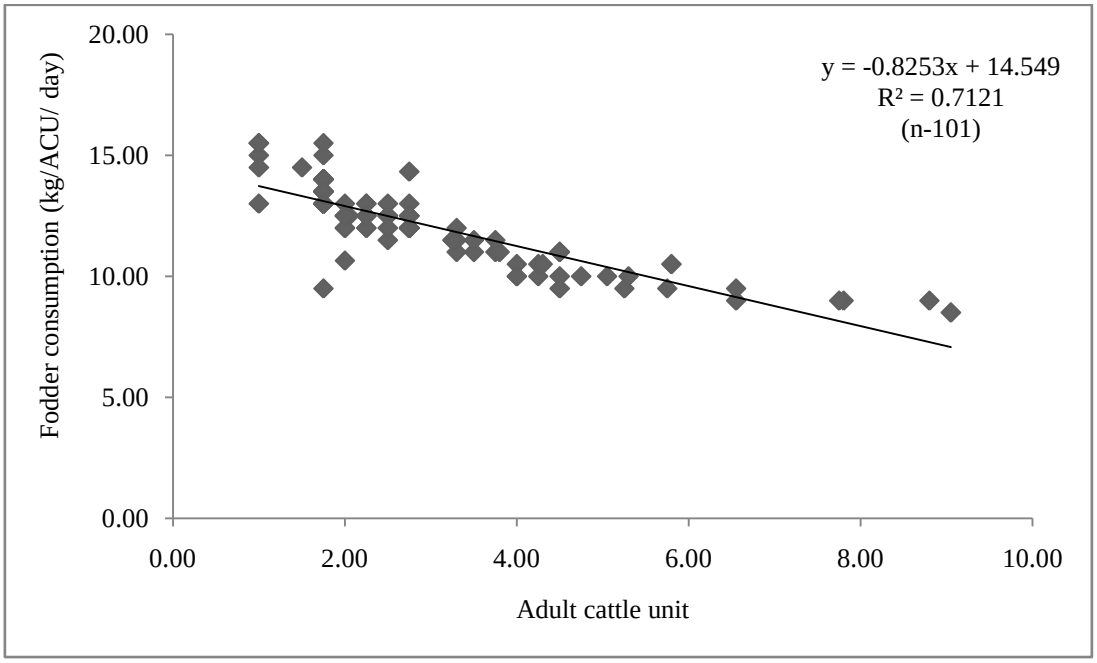


Fig. 5. Relationship between fodder consumption and total ACU per household at <800 m altitude

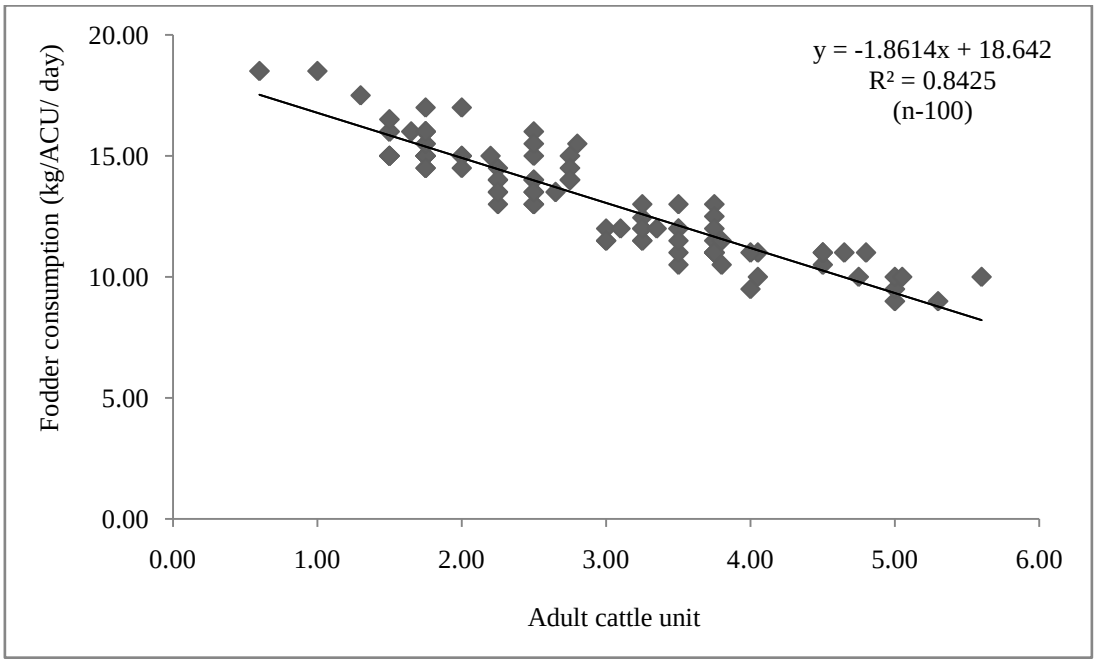


Fig. 6. Relationship between fodder consumption and total ACU per household at 801-1200 m altitude

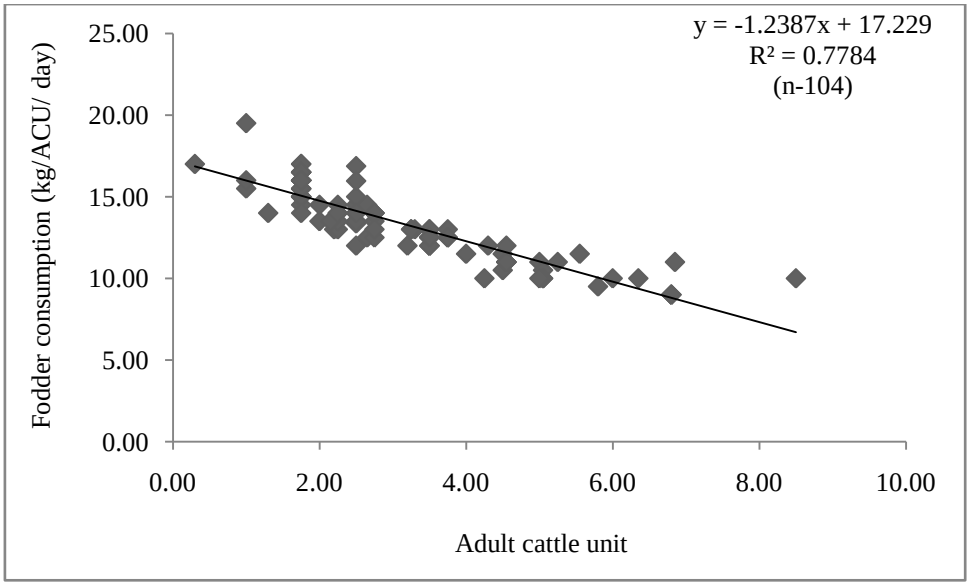


Fig. 7. Relationship between fodder consumption and total ACU per household at 1201-1600 m altitude

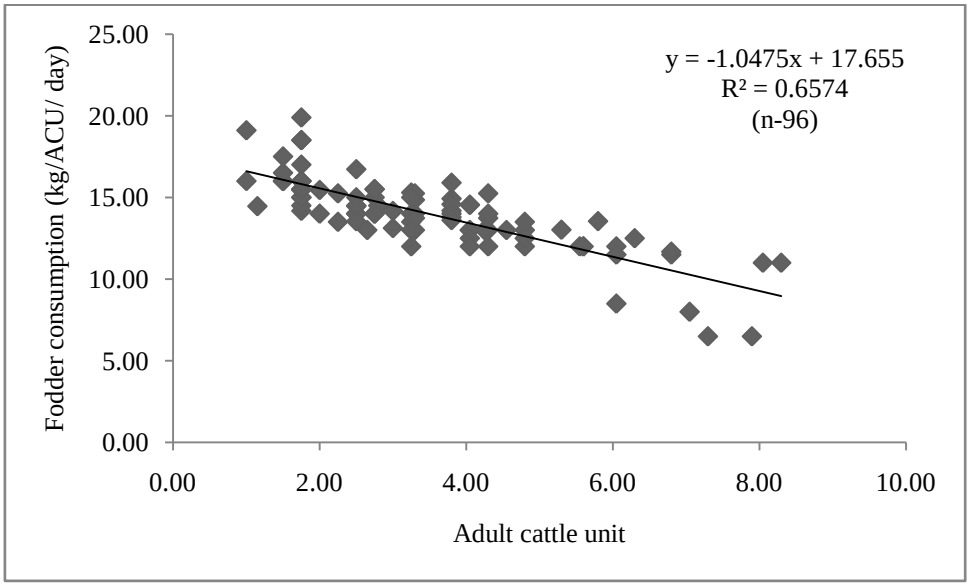


Fig. 8. Relationship between fodder consumption and total ACU per household at >1600 m altitude

CONCLUSION

Agroforestry practices help in reducing the gap between demand and supply of fuelwood and fodder as well as pressure on natural forests, and can be an effective approach in achieving the objectives of the National Forest Policy (1988) in India.

This study produced comprehensive information on the use of farm trees for meeting energy needs among smallholders in the Garhwal Himalayan region, India. The estimated results revealed that contribution of agroforestry for fuelwood and fodder was observed maximum in 1201-1600m altitude while minimum was at altitude >1600 m. Therefore the results suggest more adoption of agroforestry practices must be encouraged at higher altitude to fulfill the requirement of fuelwood and fodder in addition to other services such as fruit, timber, fiber, bio-sticks etc. The estimates of the study will also be helpful in identifying the role of agroforestry in forest management and minimizing the anthropogenic pressure. This can be achieved through government initiatives such as providing suitable planting material at a low cost to support livelihoods which will consequently assist in climate change mitigation and adaptation.

Need of effective communication with rural smallholders on the multifunctional values of agroforestry adoption and a better understanding of the importance of planting suitable tree species for multipurpose uses and their integration into farming systems in the mountainous region is of great importance in order to enhance agroforestry practices.

REFERENCES

Ali, J. and Benjamisen, A. (2004). Fuelwood, timber and deforestation in the Himalayas. The case of Basho valley, Baltistan region, Pakistan. Mountain Research and Development, 24(4): 312–318.

Asik, S.M.U. and Masakazu, T. (2017). Fuelwood consumption and its impact on forests in the teknaf peninsula on the southern coast of Bangladesh. American Journal of Environmental Sciences, 13(3): 225-232.

Bagwari, H.K. and Todaria, N.P. (2011). Resource use pattern and agroecosystem functioning in Rawanganga micro-watershed in Garhwal Himalaya, India Journal of Agriculture and Rural Development in the Tropics and Subtropics, 112(2): 101–112.

Bhatt, B.P. and Badoni, A.K. (1995). Remarks on fodder plants of Garhwal Himalaya. In Chadha, S K (ed) Echoes of Environment 1995, pp 52-75, Himalaya Publishing House, New Delhi.

Bhatt, B.P. and Sachan, M.S. (2004). Firewood consumption along an altitudinal gradient in mountain villages of India. Biomass and Bioenergy, 27: 69-75

Bhatt, B.P. and Todaria, N.P. (1999). Agroforestry operational Research and training Project for the Development of Non-Forested Wastelands in Garhwal Hills. Progress Report Submitted to Ministry of Rural Areas and Employment, Department of Wasteland Development, Govt. of India, New Delhi 1999, pp: 25.

Bhatt, B.P., Negi, A.K. and Todaria, N.P. (1994). Fuelwood consumption pattern at different altitudes in Garhwal Himalaya. Energy, 19 (4): 465–468.

Bhatt, V.P. (2002). Germination behavior of Ficus Species in Garhwal Himalaya. Ph.D. thesis submitted to HNB Garhwal University, Srinagar-Garhwal, Uttarakhand, India.

Chettri, N., Sharma, E., Deb, D.C. and Sundriyal, R.C. (2002). Impact of firewood extraction on tree structure, regeneration and wood biomass productivity in a trekking corridor of the Sikkim Himalaya. Mountain Research and Development, 22(2):150–158.

Dhanai, R., Negi, R.S., Parmar, M.K. and Singh, S. (2014). Fuelwood and fodder consumption pattern in Himalayan watershed, International Journal of Environmental Biology, 4 (1): 35-40.

Duke, G. (1994). A participatory approach to conservation safeguarding the Himalayan forests of the Palas valley, District Kohistan. In: Asian Study Group (Afghanistan Circle), editor. The destruction of the forests and wooden architecture of Eastern Afghanistan and North Pakistan: Nuristan to Baltistan, Islamabad. Pakistan: Asian Study Group. pp. 40–48.

GBPIEHD (1980). Integrated natural and human resource planning and management in the hills of U.P. Pantnagar: progress report of subproject: Study of Grassland and Livestock Resources Management in the Kumaun Hills.

IMD (2017). Rainfall statistics of India - 2017. India Meteorological Department (Ministry of Earth Sciences). http://hydro.imd.gov.in/hydrometweb/(S(lgildb55hwbltm45tpuuxs45))/PRODUCTS/Publications/Rainfall%20Statistics%20of%20India%20%202017/Rainfal%20Statistics%20of%20India%20%202017.pdf [accessed on 20/01/2018].

Khuman, Y.S.C., Pandey, R. and Rao, K.S. (2011). Fuelwood consumption patterns in Fakot watershed, Garhwal Himalaya, Uttarakhand, Energy, 36 (8): 4769-4776.

Kumar, M. and Sharma, C.M. (2009). Fuelwood consumption pattern at different altitudes in rural areas of Garhwal Himalaya. Biomass and Bioenergy, 33: 413-1418.

Kumar, M., Sharma, C.M. and Rajwar, G.S. (2009). Energy budget of traditional hill agroecosystems along altitudinal gradients in Garhwal Himalaya, India. World Journal of Agricultural Sciences, 5(6): 729-736.

Mahato, S. (2017). Provisioning and regulating services under contrasting size and management of Oak forests in Garhwal Himalayas, India. Ph.D. thesis submitted to HNB GarhwalUniversity, Srinagar-Garhwal, Uttarakhand, India.

Maikhuri, R.K., Semwal, R.L., Rao, K.S. and Saxena, K.G. (1996). Traditional crop diversity for sustainable development of central Himalayan agroecosystems. Intenational Journal of Sustainable Development and World Ecology, 1: 56-68.

Malik, Z.A., Bhat, J.A. and Bhatt A.B. (2014). Forest resource use pattern in Kedarnath wildlife sanctuary and its fringe areas (a case study from Western Himalaya, India). Energy Policy, 67:138–145.

Mitchell, R. (1979). An analysis of Indian agroecosystem. Interprint, New Delhi, India.

Negi, A.K. and Todaria, N.P. (1993). Studies on the impact of local folk on forests of Garhwal Himalaya. 1: energy from biomass. Biomass and Bioenergy, 4(6): 447–454.

Pandey, D. (2002). Fuelwood studies in India: Myth and reality, CIFOR, ISBN 979-8764-92-7.

Pandey, R. (2011a). Consumption and valuation of livestock fodder under different forest types of Himalayas, India. Silva Lusitana, 19(2): 207-219.

Pandey, R. (2011b). Forest biomass extraction for livestock feed and associated carbon analysis in lower Himalayas, India, Mitigation and Adaptation Strategies for Global Change, 16 (8): 879-888.

Ramakrishnan, P.S. (2005). Mountain Biodiversity, Land Use Dynamics and Traditional Ecological Knowledge. In: Huber U.M., Bugmann H.K.M., Reasoner M.A. (eds) Global Change and Mountain Regions. Advances in Global Change Research, vol 23. Springer, Dordrecht.

Ravindranath, N.H., Somashekar, H.I., Nagaraja, M.S., Sudha, P., Sangeeta, G., Bhattacharya, S.C.

and Salam, P.A. (2005). Assessment of Sustainable non-planted biomass resources potential for energy in India. Biomass and Bioenergy, 29:178-190.

Rawat, S., Kumar, M., Pandey, R. and Nagar, B. (2018). Forest resource utilization pattern and heterogeneity in rural household characteristics in Garhwal Himalaya. Indian Forester, 144(2): 150-158.

Rawat, Y.S., Vishvakarma, S.C.R. and Todaria, N.P. (2009). Fuelwood Consumption Pattern of Tribal Communities in Cold Desert of Lahaul Valley, North-Western Himalaya, India. Biomass and Energy, 33: 1547–1557.

Schickhoff, U. (1995). Himalayan forests cover change in historical perspective: A case study from the Kaghan valley, Northern Pakistan. Mountain Research and Development, 15(1): 3–18.

Semwal, R.L. and Maikhuri, R.K. (1996). Agroecosystem analysis of Garhwal Himalaya. Biological Agriculture and Horticulture, 13: 267-189.

Sharma, C.M., Gairola, S., Kumar, M., Rawat, Y.S. and Bagwari, H.K. (2009). Resource utilization in village ecosystem of temperate zone of Garhwal Himalaya. Indian Journal of Agroforestry, 11(2): 94-100.

Singh, G., Rawat, G.S. and Verma, D. (2010). Comparative study of fuelwood consumption by villagers and seasonal 'Dhaba owners'' in the tourist affected regions of Garhwal Himalaya, India. Energy Policy, 38: 1895-1899.

Singh, N. and Sundriyal, R.C. (2009). Fuelwood, fodder consumption and deficit pattern in Central Himalayan village, Nature and Science, 7 (4): 85-88.

Tucker, R.P. (1987). Dimensions of deforestation in the Himalayas: the historical settings. Mountain Research and Development, 7(3): 328–331.

Yang, W.Y. (1971). Methods of farm management investigation, Agricultural Development Paper no. 8. FAO, Rome.

RESEARCH ARTICLE

SEASONAL INCIDENCE OF MAJOR INSECT PESTS OF POTATO CROP IN WESTERN U.P

Rohit Malik*, D.V.Singh, Gaje Singh, S.K. Sachan, Prashant Mishra, Bijendra Singh and J. Kaushik

Department of Entomology, SardarVallabhbhai Patel University of Agriculture and Technology, Modipuram Meerut 250110, (U.P.) India
Email: rohitmalik1471992@gmail.com

Received-04.12.2018, Revised-23.12.2018

Abstract: An experiment was carried out under field conditions at the H.R.C of SardarVallabhbhai Patel University of Agriculture and technology, Meerut to study the seasonal incidence of major insect pests of potato crop during 2016-17 and 2017-18.The incidence of aphid, leafhopper and whitefly was recorded during 4th week of January (3rd meteorological standard week), the peak activity of aphid (13.89 aphid/5 plants), whitefly (15.67 whitefly/5 plants) was observed during last week of November (47th meteorological standard week) and the peak activity of leafhopper was observed during first week of December (49th meteorological standard week), respectively. The aphid population showed a significant negative correlation with maximum temperature (T_{max}) r= -0.567, p<0.05, minimum temperature (T_{min}) r= -0.648, p<0.01 and with mean temperature (T_{mean}) r= -0.452, p<0.05. The whitefly population showed a signification positive correlation with maximum temperature (T_{max}) r= 0.654, p<0.01 and mean temperature (T_{mean}) r= 0.678, p<0.01 and minimum temperature (T_{min}) r= 0.569, p<0.01. Whereas a significantly negative correlation was observed with evening relative humidity (RH_{even} r= 0.656, p<0.01 and mean relative humidity (RH_{mean}) r= 0.686, p<0.01. The leafhopper showed a significant negative correlation with minimum temperature (r= 0.583, p<0.05) and evening relative humidity (r= 0.485, p<0.05).

Keywords: Seasonal incidence, Aphid, Leafhopper, Whitefly

INTRODUCTION

Potato, *Solanum tuberosum* L. is one of the most productive and widely grown food crops in the world. It is grown on around 18.3 million hectares with a production of 295 million tonnes. In India area under potato 2.14 mha, production 43.77 million tonnes and productivity 22.09 tonnes/ha. Potato contributes about 2.48 per cent of the total agricultural output from only 1.07 per cent of the total cropped area (MoA&FW, GOI New Delhi 2017). There are various production constraints among which insect pests are the most important. Which includes, aphids (*Myzus persicae* Sulzer), thrips (*Thrips palmi* Karny), leafhopper (*Amrasca biguttula* Ishida), whitefly (*Bemisia tabaci* Genn.) and soil insects like cutworm (*Agrotis spp.)* have significant influence on potato yield (Bhatnagar, 2007; Deen, M. B. and Fayaz, A. A., 2018). Information on seasonal incidence of insect pests on potato can help to take up effective management strategies in time to bring down the population to insect pests using effective control measures. In view of this the present study on population dynamic of insect pests on potato were undertaken.

MATERIALS AND METHODS

The present investigation was carried out under field conditions at the H.R.C of SardarVallabhbhai Patel University of Agriculture and Technology, Meerut-250110 (U.P.) India. Incidence of major insect pests of potato was recorded at weekly intervals from untreated plot. The observations on incidence of whitefly, aphids and leafhopper nymphs on potato plants were recorded at weekly interval from 5 randomly selected potato plants from 3 leaves of upper, middle and lower canopy of the plant throughout the crop season and data obtained on the number of insects/ 5 plant. The daily metrological data pertaining to temperature, rainfall during experimental period was obtained. Relation between per cent infestation and metrological variables were worked out using simple correlation analysis. Simple correlation regression coefficient was done using following formula.

$$r = \frac{\sum XY - \frac{(\sum X)(\sum Y)}{N}}{\sqrt{\left(\sum X^2 - \frac{(\sum X)^2}{N}\right)\left(\sum Y^2 - \frac{(\sum Y)^2}{N}\right)}}$$

r = Correlation coefficient between X & Y
X = Nymph/larvae
Y = Meteorological parameters
N = Number of observations

RESULTS AND DISCUSSION

Seasonal incidence of Aphid population of *Myzus persicae* during *rabi*, 2016-17 and 2017-18.

The present investigation ((Table 1) the population of aphids was observed on potato crop in the range of 2.67 to 13.89 aphid per/5 plants from mid November (46th meteorological standard week) during 2016-17. The first peak was observed during mid December

*Corresponding Author

(50th meteorological standard week) with highest population (12.53 aphid per/5 plants), whereas second and highest peak of aphid population (13.89 aphid per/5 plants) was recorded during last week of January (3rd meteorological standard week) during 2016-17. Similarly, during 2017-18 aphid incidence started from last week of November (47th meteorological standard week). The first peak was observed during mid December (50th meteorological standard week) with highest population (12.40 aphid per/5 plants). Although, second and highest peak of aphid population (11.33 aphid per/5 plants) was recorded during third week of January (3rd meteorological standard week). Interestingly, during 2016-17 the population of aphid showed a significant negative correlation with maximum temperature (T_{max}) r= -0.567, p<0.05 and with mean temperature (T_{mean}) r= 0.452, p<0.05. Whereas, during 2017-18 the aphid population showed a significantly negative correlation with maximum temperature (T_{max}) r = -0.562, p<0.05, minimum temperature ($T_{min.}$) r = -0.648, p<0.01 and mean temperature (T_{mean}) r = -0.669, p<0.01. The present findings corroborates to those of Sain *et al.* (2017) who reported the population of aphid appeared in first week of November (44th standard week) in western part of Uttar Pradesh. Similarly, the present findings are also in agreement with those of Shrivastava *et al.* (1971), Pandey *et al.* (2007), Sarkar *et al.* (2008) and Shukla (2014) they reported peak activity of aphid during second fort night of January. Similarly, Panday *et al.* (2014) the peak activity of aphid population during third week of January in Pantnagar region (India). The present findings corroborates to those of Pandey *et al.* (2007), Pandey *et al.* (2008), Panday *et al. (*2014) and Shukla (2014) they reported the aphid population was significantly negatively correlated with temperature. Panday *et al. (*2014) also reported non significant positive correlation with relative humidity and rainfall. The present findings also corroborates to those of Bijjur and Verma (1986), Chaudhuri (2001) and Bana *et al.* (2012) who reported aphid population was negatively correlated with maximum temperature.

Seasonal incidence of Whitefly population of *Bemisia tabaci* during *rabi* ,2016 and 2017.

Interestingly, first incidence of whitefly was recorded in second week of November (45th meteorological standard week) and ranged from 1.33 to15.67 whitefly/5 plants during 2016-17. The highest peak of whitefly incidence (15.67 whitefly/5 plants) was observed in last week of November (47th meteorological standard week), after a highest peak during last week of November than whitefly population started to decline subsequently. Similarly, during 2017-18 incidence of whitefly was also started in first week of November (45th meteorological standard week). The first peak was observed during first week December (48th meteorological standard week) with highest population (13.00 whitefly/5 plants) and Second peak of whitefly population (11.33whitefly/5 plants) was recorded during first week of December (49th meteorological standard week). During 2016-17 the population of whitefly population showed a significant positive correlation with maximum temperature (T_{max}) r= 0.654, p<0.01 and mean temperature (T_{mean}) r= 0.678, p<0.01 and minimum temperature ($T_{min.}$) r= 0.569, p<0.05. Similarly, during 2017-18 the whitefly population showed a significantly negative correlation evening relative humidity (RH_{even}) r=-0.656, p<0.01 and mean relative humidity (RH_{mean}) r=-0.686, p<0.01. The present findings corroborates to those of Paul and Konar (2005) who reported that whitefly first appeared on the crop during first week of December with peak in last week of December. Mathur *et al.* (2012) reported peak activity of whitefly during January second week. Similarly, Rashid *et al.* (2013) and Pandey *et al.* (2014) also recorded peak activity during third week of December. Interestingly, these findings also corroborates to those of Nag (2016) who recorded two peaks of whitefly during third week of December and January. The present findings corroborates to those of Pandey *et al.* (2008), Pandey *et al.* (2014) and Kumar and Gupta (2016) who reported a significant negative correlation between *B. tabaci* population and relative humidity and a significant positive correlation between maximum and minimum temperature. Similarly, Anand (2015) showed a negative correlation for minimum temperature and positive correlation with maximum temperature and rainfall.

Seasonal incidence of Leafhopper population of *Empoasca fabae* during *rabi,*2016 and 2017.

The incidence of leafhopper was first noticed on crop in third week of November (46th meteorological standard week) during 2016-17 and leafhopper population ranged between 2.33 to 9.13 leafhopper/5 plants. Two peaks of leafhopper population were recorded, first peak was observed during last week of November (48th meteorological standard week) with highest population (9.13 leafhopper/5 plants) and second peak of leafhopper population (8.33 leafhopper/5 plants) was recorded during last week of January (4th meteorological standard week). Similarly, the incidence of leafhopper during 2017-18 was commenced during last week of November (47th meteorological standard week) and leafhopper population ranged between 3.21 to 10.6 leafhopper/5 plants. Similarly, two peaks of leafhopper population were also recorded during 2017-18, the first peak was observed during first week of December (49th meteorological standard week) with highest population (10.6 leafhopper/5 plants) and second peak of leafhopper population (6.89 leafhopper/5 plants) was recorded during week of Decembre (50th meteorological standard week). Interestingly, leafhopper population showed a non-significant negative correlation with maximum temperature and

a non-significant positive correlation with minimum temperature, mean temperature, morning relative humidity, evening relative humidity, relative humidity and rainfall was recorded during 2016-17. Whereas, during 2017-18, leafhopper population showed a significant negative correlation with minimum temperature (r=- 0.583, p<0.05) and morning relative humidity (r=- 0.485, p<0.05). These findings corroborate to those of Mathur *et al*. (2012) and Nag (2016) recorded maximum density of leafhopper during December last week and during the third week of January, respectively. The findings of present study corroborates to those of Mahmood *et al.* (2002) who reported that incidence of leafhopper, *A. biguttula biguttula* showed positive and significant correlation with maximum and minimum temperatures. Similarly, Muthu kumar and Kalyana sundaram (2003) also observed negative correlation between temperature and leafhoppers population. The findings of present study revealed that, weather parameters contribute very less to leafhopper population fluctuations.

Table 1. Seasonal incidence and correlation of aphid (*Myzus persicae)* population during crop growth period (2016-17)

S. No.	S.W.	Date	Aphid/5 Plats	Meteorological parameters						
				Temperature (^{0}C)			Relative Humidity (%)			Rain fall (mm)
				Max.	Min.	Mean	Mor.	Even.	Mean	
1.	45	**Nov, 7-13**	0	28.66	9.99	19.32	92.50	50.13	71.31	0.00
2.	46	**Nov, 14-20**	2.67	28.56	10.66	19.61	96.54	45.44	70.99	0.00
3.	47	**Nov, 21-27**	5.89	27.69	10.30	18.99	94.66	55.40	75.03	0.00
4.	48	**Nov, 28-Dec, 4**	8.53	27.43	10.21	18.82	94.74	47.34	71.04	0.00
5.	49	**Dec, 5-11**	9.67	23.21	8.90	16.06	95.91	65.93	80.92	0.00
6.	50	**Dec, 12-18**	12.53	23.14	9.36	16.25	96.03	59.89	77.96	0.00
7.	51	**Dec, 19-25**	11.89	23.90	5.64	14.77	96.00	44.53	70.26	0.00
8.	52	**Dec, 26-Jan, 1**	8.93	22.36	7.93	15.14	95.71	65.09	80.40	0.00
9.	1	**Jan, 2-8**	8.53	22.2	8.3	15.27	95.8	61.8	78.81	29.3
10	2	**Jan, 9-15**	5.21	18.5	4.3	11.41	96.9	52.2	74.53	0.0
11.	3	**Jan, 16-22**	13.89	20.1	6.7	13.41	93.9	61.7	77.79	0.0
12.	4	**Jan, 23-29**	10.53	21.8	10.7	16.25	97.7	63.7	80.66	35.7
13.	5	**29 Jan – 04 Feb**	8.53	22.0	8.7	15.34	97.5	64.0	80.78	0.0
14.	6	**Feb, 05 –11**	7.67	22.0	9.3	15.64	97.3	61.0	79.14	1.3
Correlation (r)				**-0.567**	**-0.284**	**0.452**	**-0.501**	**0.239**	**0.438**	**0.161**

Table 2. Seasonal incidence and correlation of aphid (*Myzus persicae)* population during crop growth period (2017-18)

S. No.	S.W.	Date	Aphid/5 plants	Meteorological parameters						
				Temperature (^{0}C)			Relative Humidity (%)			Rain fall (mm
				Max.	Min.	Mean	Mor.	Even.	Mean	
1.	**45**	**Nov, 7-13**	0	26.0	10.7	18.4	96.8	69.0	82.9	0.0

2.	**46**	**Nov, 14-20**	0	27.7	13.1	20.4	94.8	52.7	73.8	0.0
3.	**47**	**Nov, 21-27**	4.21	25.1	6.7	15.9	95.0	28.1	61.5	0.0
4.	**48**	**Nov, 28-Dec, 4**	8.59	24.9	6.1	15.5	95.7	28.4	62.1	0.0
5.	**49**	**Dec, 5-11**	10.4	24.3	7.9	16.1	87.7	28.6	58.2	0.0
6.	**50**	**Dec, 12-18**	12.4	20.0	8.4	14.2	90.9	52.1	71.5	10.0
7.	**51**	**Dec, 19-25**	11.33	23.3	7.9	15.6	96.3	38.1	67.2	0.0
8.	**52**	**Dec, 26-Jan, 1**	8.53	23.0	6.4	14.7	94.3	41.9	68.1	0.0
9.	**1**	**Jan, 2-8**	8.21	15.4	5.9	10.6	91.9	68.7	80.3	0.0
10	**2**	**Jan, 9-15**	8.33	21.9	6.4	14.1	96.0	35.9	65.9	0.0
11.	**3**	**Jan, 16-22**	9.67	23.6	6.9	15.2	91.7	40.4	66.1	0.0
12.	**4**	**Jan, 23-29**	9	19.7	6.6	13.1	94.3	55.3	74.8	0.0
13.	**5**	**29 Jan – 04 Feb**	7.07	24.7	7.8	16.2	94.4	32.9	63.6	0.0
14.	**6**	**Feb, 05 –11**	6.73	23.9	6.6	15.2	90.6	26.6	58.6	0.0
	Correlation (r)			**-0.562**	**-0.648**	**-0.669**	**0.137**	**-0.296**	**-0.562**	**0.380**

Table-3. Seasonal incidence and correlation of whitefly (*Bemisia tabaci)* population during crop growth period (2016-17)

S. No.	**S.W.**	**Date**	**Whitefly/5 plants**	**Meteorological parameters**						
				Temperature (^{0}C)			**Relative Humidity (%)**			**Rain fall (mm)**
				Max.	**Min.**	**Mean**	**Mor.**	**Even.**	**mean**	
1.	**45**	**Nov, 7-13**	3.6	28.66	9.99	19.32	92.50	50.13	71.31	0.00
2.	**46**	**Nov, 14-20**	10.2	28.56	10.66	19.61	96.54	45.44	70.99	0.00
3.	**47**	**Nov, 21-27**	15.67	27.69	10.30	18.99	94.66	55.40	75.03	0.00
4.	**48**	**Nov, 28-Dec, 4**	7.67	27.43	10.21	18.82	94.74	47.34	71.04	0.00
5.	**49**	**Dec, 5-11**	7.33	23.21	8.90	16.06	95.91	65.93	80.92	0.00
6.	**50**	**Dec, 12-18**	4.98	23.14	9.36	16.25	96.03	59.89	77.96	0.00
7.	**51**	**Dec, 19-25**	3.6	23.90	5.64	14.77	96.00	44.53	70.26	0.00
8.	**52**	**Dec, 26-Jan, 1**	2.66	22.36	7.93	15.14	95.71	65.09	80.40	0.00
9.	**1**	**Jan, 2-8**	2.33	22.2	8.3	15.27	95.8	61.8	78.81	29.3
10	**2**	**Jan, 9-15**	1.33	18.5	4.3	11.41	96.9	52.2	74.53	0.0
11.	**3**	**Jan, 16-22**	1.33	20.1	6.7	13.41	93.9	61.7	77.79	0.0
12.	**4**	**Jan, 23-29**	2.66	21.8	10.7	16.25	97.7	63.7	80.66	35.7

13.	**5**	**29 Jan – 04 Feb**	3.67	22.0	8.7	15.34	97.5	64.0	80.78	0.0
14.	**6**	**Feb, 05 – 11**	8.4	22.0	9.3	15.64	97.3	61.0	79.14	1.3
	Correlation (r)			**0.654**	**0.569**	**0.678**	**-0.064**	**-0.242**	**-0.238**	**-0.294**

Table 4. Seasonal incidence of whitefly(*Bemisia tabaci)* population during crop growth period (2017-18)

S. No.	**S.W.**	**Date**	**Whitefly/ 5 plants**	**Meteorological parameters**						
				Temperature (^{0}C)			**Relative Humidity (%)**			**Rain fall (mm)**
				Max.	**Min.**	**Mean**	**Mor.**	**Even.**	**Mean**	
1.	**45**	**Nov, 7-13**	0.87	26.0	10.7	18.4	96.8	69.0	82.9	0.0
2.	**46**	**Nov, 14-20**	1.67	27.7	13.1	20.4	94.8	52.7	73.8	0.0
3.	**47**	**Nov, 21-27**	10	25.1	6.7	15.9	95.0	28.1	61.55	0.0
4.	**48**	**Nov, 28-Dec, 4**	13	24.9	6.1	15.5	95.7	28.4	62.1	0.0
5.	**49**	**Dec, 5-11**	11.33	24.3	7.9	16.1	87.7	28.6	58.2	0.0
6.	**50**	**Dec, 12-18**	6.4	20.0	8.4	14.2	90.9	52.1	71.5	10.0
7.	**51**	**Dec, 19-25**	5.33	23.3	7.9	15.6	96.3	38.1	67.2	0.0
8.	**52**	**Dec, 26-Jan, 1**	5.2	23.0	6.4	14.7	94.3	41.9	68.1	0.0
9.	**1**	**Jan, 2-8**	2.2	15.4	5.9	10.6	91.9	68.7	80.3	0.0
10	**2**	**Jan, 9-15**	3	21.9	6.4	14.1	96.0	35.9	65.9	0.0
11.	**3**	**Jan, 16-22**	3.46	23.6	6.9	15.2	91.7	40.4	66.1	0.0
12.	**4**	**Jan, 23-29**	3.53	19.7	6.6	13.1	94.3	55.3	74.8	0.0
13.	**5**	**29 Jan – 04 Feb**	4.13	24.7	7.8	16.2	94.4	32.9	63.6	0.0
14.	**6**	**Feb, 05 –11**	4.07	23.9	6.6	15.2	90.6	26.6	58.6	0.0
Correlation (r)				**0.177**	**-0.353**	**-0.036**	**-0.432**	**-0.656**	**-0.686**	**0.086**

Table 5. Seasonal incidence and correlation of leafhopper (*Empoasca fabae*) during crop growth period (2016-17)

S.W.	**Date**	**Leafhopper/5 plants**	**Meteorological parameters**						
			Temperature (^{0}C)			**Relative Humidity (%)**			**Rain fall (mm**
			Max.	**Min.**	**Mean**	**Mor.**	**Even.**	**mean**	
45	**Nov, 7-13**	0	28.66	9.99	19.32	92.50	50.13	71.31	0.00
46	**Nov, 14-20**	3.13	28.56	10.66	19.61	96.54	45.44	70.99	0.00
47	**Nov, 21-27**	5.27	27.69	10.30	18.99	94.66	55.40	75.03	0.00
48	**Nov, 28-Dec, 4**	9.13	27.43	10.21	18.82	94.74	47.34	71.04	0.00

49	**Dec, 5-11**	5.4	23.21	8.90	16.06	95.91	65.93	80.92	0.00
50	**Dec, 12-18**	4.73	23.14	9.36	16.25	96.03	59.89	77.96	0.00
51	**Dec, 19-25**	4.33	23.90	5.64	14.77	96.00	44.53	70.26	0.00
52	**Dec, 26-Jan, 1**	4.13	22.36	7.93	15.14	95.71	65.09	80.40	0.00
1	**Jan, 2-8**	3.67	22.2	8.3	15.27	95.8	61.8	78.81	29.3
2	**Jan, 9-15**	2.33	18.5	4.3	11.41	96.9	52.2	74.53	0.0
3	**Jan, 16-22**	5.67	20.1	6.7	13.41	93.9	61.7	77.79	0.0
4	**Jan, 23-29**	8.33	21.8	10.7	16.25	97.7	63.7	80.66	35.7
5	**29 Jan – 04 Feb**	7.67	22.0	8.7	15.34	97.5	64.0	80.78	0.0
6	**Feb, 05 –11**	5.4	22.0	9.3	15.64	97.3	61.0	79.14	1.3
Correlation (r)			**-0.149**	**0.283**	**0.016**	**0.389**	**0.301**	**0.350**	**0.228**

Table 6. Seasonal incidence and correlation of leafhopper (*Empoasca fabae*) during crop growth period (2017-18)

S.W.	**Date**	**Leafhopper/5 plants**	**Meteorological parameters**						
			Temperature (^{0}C)			**Relative Humidity (%)**			**Rain fall (mm)**
			Max.	**Min.**	**Mean**	**Mor.**	**Even.**	**Mean**	
45	**Nov, 7-13**	0	26.0	10.7	18.4	96.8	69.0	82.9	0.0
46	**Nov, 14-20**	0	27.7	13.1	20.4	94.8	52.7	73.8	0.0
47	**Nov, 21-27**	3.93	25.1	6.7	15.9	95.0	28.1	61.55	0.0
48	**Nov, 28-Dec, 4**	8	24.9	6.1	15.5	95.7	28.4	62.1	0.0
49	**Dec, 5-11**	10.6	24.3	7.9	16.1	87.7	28.6	58.2	0.0
50	**Dec, 12-18**	6.89	20.0	8.4	14.2	90.9	52.1	71.5	10.0
51	**Dec, 19-25**	4.56	23.3	7.9	15.6	96.3	38.1	67.2	0.0
52	**Dec, 26-Jan, 1**	6.53	23.0	6.4	14.7	94.3	41.9	68.1	0.0
1	**Jan, 2-8**	5.23	15.4	5.9	10.6	91.9	68.7	80.3	0.0
2	**Jan, 9-15**	3.21	21.9	6.4	14.1	96.0	35.9	65.9	0.0
3	**Jan, 16-22**	4.6	23.6	6.9	15.2	91.7	40.4	66.1	0.0
4	**Jan, 23-29**	4.6	19.7	6.6	13.1	94.3	55.3	74.8	0.0
5	**29 Jan – 04 Feb**	5.27	24.7	7.8	16.2	94.4	32.9	63.6	0.0
6	**Feb, 05 –11**	4.93	23.9	6.6	15.2	90.6	26.6	58.6	0.0
Correlation (r)			**-0.286**	**-0.583**	**-0.453**	**-0.067**	**-0.485**	**-0.286**	**0.207**

REFERENCES

A**nand** (2015). Efficacy of Newer Insecticides against Leafhopper and Whitefly Infesting Brinjal and its Effect on Coccinellids. *Pesticide Research Journal,* **25**(1): 6-11.

Bana, Jugal, Jat, B. C., Bajya and Dewa (2012). Seasonal incidence of major insect pests of cabbage and their natural enemies in relation to weather parameters. *Indian Journal of Entomology*, **74**: 236-240.

Bhatnagar (2007). Incidence and succession of thrips, leafhoppers and whitefly in combination of planting dates and potato varieties. *Ann. Pl. Prot. Sci*., **15**(1): 101-105

Bijjur, S. and Verma, S. (1996). Effect of abiotic factors on the pests of pea and natural enemies. Indian Journal of Entomology, **57**(3): 233-239.

Chaudhuri, N., Ghosh, S. and Senapati, S. K. (2001). Incidence of insect pests of cabbage in relation to prevailing climate conditions of terai region. *Indian Journal of Entomology*, **63**: 421-428.

Deen, M. B. and Fayaz, A. A. (2018). A Systematic checklist and species richness of insect pests associated with vegetable crops in Jammu & Kashmir State (India). *Journal of Entomology and Zoology Studies*; **6**(2): 328-338.

Mahmood, M., Hussain, S. I., Khokar, K. M,. Jeelani, G. and Ahmad, M. (2002). Population Dynamic of Leafhopper (Amrasca Biguttula Biguttula) on Brinjal And Effects of Abiotic Factors on Its Dynamics. *Asian J. Pl. Sci*., **1**: 403-404.

Mathur, A., Singh, N. P., Meena, M. and Singh, S. (2012). Seasonal incidence and effect of abiotic factors on population dynamics of major insect pests on brinjal crop. J. Environ. Res. and develop, **1**(7): 53-55.

MoA & FW and GOI (2017). Department of Agriculture Cooperation & Farmers Welfare New Delhi.

Kumar, M. and Gupta, A. (2016). Effect of weather variableson whitefly *(Bemisia tabaci* Gennadius) population in development of potato apical leaf curl virus disease. *J Agrometeorol*. 18(2): 288-291

Muthu kumar, M. and Kalyana, S. (2003). Influence of abiotic factors on the incidence of major insect pests in Brinjal (*Solanum melongena* L.). *South India Horticulture*.**51** (1-6): 214-218.

Nag, D. (2016). Seasonal incidence and management of major insect pests on *rabi* potato at Raipur M.Sc. (Ag) Thesis1-130.

Pandey, R., Rai, M. K., Sharma, K. and Chaudhari, D. (2007). Studies on population dynamics of *Myzus persicae* on potato crop with special reference to its relation with various weather parameters. Veg. Sci., 34(2): 167-169.

Pandey, R., Bisht, R. S. and Chaudhari, D. (2014). Impact of various weather parameters on population build up of insect pest of potato crop at Pantnagar. *International Journal of Basic and Applied Agricultural Research*,**12**(3): 347-350.

Pandey, R., Sharma, K. and Chaudhari, D. (2008). Effect of weather parameters on incidence of *Bemisia tabaci* and *Myzus persicae* on potato. *Annals of Plant Protection Sciences*, **16**(1): 78-80.

Paul, S. and Konar, A. (2005). Population dynamics of whitefly on potato planted ondifferent dates. Tat. J., 1; 251.

Rashid, M. H., Khatun, M. J., Mahfuz, M. S., Dash, C. K. and Hussain, M. A. (2013). Seasonal fluctuation of insect pests of brinjal at agricultural research station. *International Journal of Experimental Agriculture*, **3**(1): 4- 8

Sarkar, A., Konar, A., Hazra, S. and Choudhuri, S. (2008). Incidence and chemical control on Mustard in new alluvial zone of west Bengal. *Journal of Entomological Research*, **31**(1):41-43.

Sain, Y., Singh, R. and Kumar, S. (2017). Seasonal incidence of cabbage aphid, *Lipaphis erysimi* (Kalt.) (Hemiptera: Aphididae) in Meerut region, Uttar Pradesh. *Journal of Entomology and Zoology Studies*, **5**(6): 314-317.

Srivastava, A. S., Katiyar, S. S. L., Awasthi, B. K., Srivastava, K. M. and Nigam, P. M. (1971). Field assessment of aphid population on potato crop. *Zeitschriftfur angewandte Entomologir*, **69.1**(4): 44-48.

Shukla, K. R. (2014). Seasonal incidence of sucking pest and their natural enemies on potato. Environ. Ent., **54**(3): 11-13.

RESEARCH ARTICLE

IMMUNOMODULATORY ACTIVITY OF *CASTELA TEXANA* METHANOLIC-EXTRACT ON THE PRODUCTION OF NITRIC OXIDE IN MURINE MACROPHAGES

Hernández-Ramos Reyna-Margarita[1], Hernández-Herrera Alejandro[1], Hernández-Nava Angélica[1,2], Castillo-Maldonado Irais[1], Rivera-Guillén Mario-Alberto[3], García-Garza Rubén[4], Ramírez-Moreno Agustina[5], Serrano-Gallardo Luis-Benjamín[1] and Pedroza-Escobar David*

[1]Departamento de Bioquímica y Fitofarmacología del Centro de Investigación Biomédica de la Facultad de Medicina.Universidad Autónoma de Coahuila Unidad Torreón (UA de C), México
[2]Universidad Politécnica de Gómez Palacio, México
[3]Laboratorio de Salud Ambiental y Química Analítica del Departamento de Bioquímica y Fitofarmacología. Centro de Investigación Biomédica de la Facultad de Medicina (UA de C), México
[4]Departamento de Histología de la Facultad de Medicina (UA de C), México
[5]Facultad de Ciencias Biológicas Unidad Torreón (UA de C)
[6]Centro de Actividades Multidisciplinarias de Prevención CAMP, A.C., Torreón, México
Email: dpedroza@uadec.edu.mx

Received-06.12.2018, Revised-27.12.2018

Abstract: *Castela texana* (Torr. & A. Gray) *Rose* is a native plant to the arid regions of northern Mexico, whose medicinal properties includes antipyretic, antiparasitic, antibacterial and immunomodulatory activity. The objective of this work was to evaluate the immunomodulatory activity of the methanolic-extract of *Castela texana* leaf on the production of nitric oxide in murine peritoneal macrophages, since these cells are the major players of the first line of defense of the immune response. The citotoxicity of *Castela texana* methanolic-extracts (10, 100 and 1000 µg/mL) was evaluated with a haemolytic activity model. Then thioglycollate-elicited peritoneal cells were cultured and tested for nitric oxide production, which was determined by Griess method at 6, 12 and 24 h post-treatment within the following experimental groups 1) Negative control supplemented with 2% PBS, 2) Positive control supplemented with 2% LPS extract, 3) Positive control supplemented with 2% complete Freund´s adjuvant, and 4) *Castela texana* supplemented with 2% methanolic-extract 10 µg/mL. The *Castela texana* methanolic-extract showed a high cytotoxic activity so only the lowest concentration (10 µg/mL) was evaluated on the production of nitric oxide in murine macrophages. The *Castela texana* extract triggered a high production of nitric oxide at short times (6 and 12 h) compared to the concentration of nitric oxide induced by the positive controls with LPS and complete Freund's adjuvant. It can be concluded that this extract may act as an acute activator of nitric oxide production in macrophages, settling an antecedent to study the use of *Castela texana* compounds as immunological adjuvants.

Keywords: *Castela texana,* Nitric oxide, Murine macrophages

INTRODUCTION

Castela texana (Torr. & A. Gray) Rose; is known in Mexico with the following spanish common names: *"Chaparro amargoso", "bisbirinda"* and *"amargoso"*. Other english common names are: *"Crucifixion thorn", "Crown-of thorns", "Goat bush", "Holacantha"* and *"Bitter bark"* (Gonzalez-Stuart, 2019). This plant belongs to the *Simaroubaceae* family and is native to the arid regions of northern Mexico, its habitat is distributed in the Mexican states of Chihuahua, Durango, Tamaulipas, San Luis Potosi and Nuevo Leon (Standley, 1923; Uphof, 1968; Martínez, 1959; Canell & Johnson, 1970).

A large variety of secondary compounds derived from the primary metabolism of plants have been reported in their leaves, flowers and fruits; highlighting, alkaloids, phenols, flavonoids, tannins, terpenes such as the quasinoids *e.g.* chaparrin, and glycosides *e.g.* castelin, castelagenin and amargosin, they all are compounds to which the bitter flavor of this plant is attributed to. Among the medicinal properties of the *Castela texana* it can be mentioned the antipyretic, antiparasitic, antibacterial and immunomodulatory activity (Calzado-Flores *et al.,* 1991, 1995, 1998).It is worth mentioning that its medicinal use must be dosed with caution since some authors have reported intoxication cases (Calzado-Flores *et al*., 2007).

Immune response and macrophages

The immune response is divided into 1) innate and 2) adaptive. Some cells that belong to the innate immune response are macrophages, neutrophils and eosinophils. In the case of the adaptive immune response, some cells are B and T lymphocytes. The innate immune response represents the first line of defense of the organism, which is characterized by being non-specific and fast to occur. On the other hand, the adaptive immune response consists of a complex process of recognition, antigenic presentation, activation and cell differentiation whose response time is slower compared to the innate immune response (Nathan, 1987; Riera *et al.,* 2016).

*Corresponding Author

Macrophages are a type of white blood cell and are the major players in the innate immune response. These cells are able to cross the epithelium of the capillaries and penetrate the connective tissue. They can ingest bacteria, damaged cells and foreign substances through a process called phagocytosis (Abbas *et al.,* 2003; Celada & Nathan, 1994) and later they can destroy these agents due to the secretion of certain enzymes and some chemical compounds such as nitric oxide and reactive oxygen species (Aliprantis *et al*., 1996; Martínez & Bordon, 2014). The immunomodulatory functions of the macrophage depend on its activation by sensitization signals, mainly induced by cytokines, and some molecules called Pathogen-associated molecular patterns (PAMPs) as lipopolysaccharide (LPS) (Pedroza-Escobar, 2016; Mac Micking *et al.*, 1997; Gorocica *et al.*, 1999).

The objective of this work was to evaluate the immunomodulatory activity of the methanolic-extract of *Castela texana* leaf on the production of nitric oxide (NO) in murine peritoneal macrophages. Since, as already mentioned, these cells are the major players of the first line of defense of the immune response, and the mechanisms of action of the active compound, of this plant that could be associated with their medicinal effects are not known.

MATERIALS AND METHODS

Biological material

All protocols used in this study were approved by the Bioethics committee of the Faculty of Medicine, Universidad Autonoma de Coahuila Unidad Torreon (reference number CB071117).

The aerial part (leaves and stem) of the *Castela texana* plant was collected in the town of Pedriceña Durango, in the month of April of the year 2015 on the Pedriceña-Nazas road, coordinates 25°, 07'44.60¨ N 103° 48' 24 .22¨ W. A voucher specimen (Ct071117) was deposited and identified in the Phytopharmacology laboratory of the Departamento de Bioquimica of the Facultad de Medicina (UA de C). After being collected, the leaves were rinsed several times with tap water, after washing they were separated and allowed to dry at room temperature on brown paper for a week. After drying, grinding was carried out with a manual mill, then they obtained powder was weighed 100 g and mixed with 900 mL of methanol and kept in a shaking incubator at room temperature for 3 days. Subsequently the supernatant was filtered on Whatman No. 2 filter paper and the filtered solution was concentrated in a rotary evaporator at 60° C. The remnant humidity was eliminated for 72 hours in a hot air oven at 40° C. The extract was stored until use at a temperature of -20° C.

A group of five *Long-evans black* female rats with an age of 12 weeks old, weighing 150 to 200 grams were used. The animals were housed in plastic boxes using sawdust as bedding with stainless steel grill covers. Water and food were offered *ad libitum*. The environmental parameters were monitored by means of a temperature and relative humidity meter. The photoperiod was 12 hours of light and 12 hours of dark.

Citotoxicity assay with the haemolytic activity model

An aliquot of 50 µL of rat's blood with EDTA anticoagulant was washed 3 times with 950 µL of 0.89% NaCl sterile saline solution with centrifugation at 3500 rpm for 5 minutes. After the third wash, the cell pellet was re-suspended in a final volume of 50 µL of saline solution. Next, 950 µL of the extract to be evaluated was added in the saline solution at 10, 100 and 1000 µg/mL concentrations. The samples were incubated for 30 minutes at 37° C, then the sample was centrifuged again at 3500 rpm for 5 minutes, and the free hemoglobin was measured to the supernatant with a spectrophotometer at 412 nm. Saline solution (0 µg/mL of the extract) and distilled water were used as negative and positive haemolytic controls, respectively.

Thioglycollate-elicited peritoneal cells

Peritoneal macrophages were recruited with 1 mL of sterile thiogliocolate solution applied intraperitoneally at a concentration of 15 µg/mL with a 20 G needle. After 3 days, 5 mL of sterile phosphate buffered saline (PBS) was injected at 4 °C into the peritoneal cavity and the abdomen of the rat was massaged for 15 seconds. Then the largest possible amount of PBS was collected (approximately 4 mL). The recovered fluid was placed in 15 mL conical tubes and the sample was centrifuged at 3500 rpm for 5 minutes. The cell pellet was re-suspended in 5 mL of Hank's Balanced Salt Solution (HBSS). The recovered cells were counted with 20 µL of Tripan Blue Solution 1: 1.

Purification of LPS from E-coli by hot aqueous-phenol extraction

An overnight culture of E-coli (DH5α) in 5 mL of Luria Broth (LB) incubated at 37 °C, was employed to prepare 1.5 mL of dilution based on Optic Density 600 nm until reaching a value of 0.5 (McFarland Standard No 3, *i.e*. approximately a cell density of 9 x 10^8 CFU/mL) The sample was centrifuged 5 minutes at 10,000 rpm and the pellet was re-suspended in 200 µL of SDS Buffer (50 mM DTT, 2% SDS, 10% glycerol, 0.05M Tris-HCl (pH 6.8), 0.01% Bromophenol Blue). The sample was boiled 15 minutes and once cold, 20 µL of Proteinase K (20 mg/mL) were added. The sample was incubated overnight at 59 °C. The following washes were done twice; first 200 µL of Tris-HCl-Saturated phenol were added, the sample was vortexed and incubated 15 minutes at 65 °C, once cold 1 mL of diethyl ether

was added and vortexed, the sample was centrifuged at full speed for 10 minutes and the bottom blue layer transferred to a new tube. Finally the LPS extract was re-suspended in 1.5 mL of sterile water.

NO quantification by the Griess method

A serial two-fold dilution curve was prepared from a 100 µM $NaNO_2$ solution. The final concentrations of the curve were 100, 50, 25, 12.5, 6.25, 3.13, 1.56, and 0 µM in a volume of 500 µL. in the case of the samples an aliquot of 500 µL was used. Then 500 µL of 1% sulfanilamide in 5% phosphoric acid, and 500 µL of 0.1% N-(1-Naphthyl)ethylenediamine dihydrochloride solution were added. The curve and samples were incubated for 5 minutes and the absorbance was read at 550 nm.

Experimental procedures

Peritoneal cells were cultured in 50 mm petri dishes, at a concentration of 2 million on each dish in 3 mL HBSS at 37 °C with 5% CO_2 for 24 h. The experimental groups included were 1) Negative control supplemented with 2% PBS, 2) Positive control supplemented with 2% LPS extract, 3) Positive control supplemented with 2% complete Freund´s adjuvant, and 4) *Castela texana* supplemented with 2% methanolic-extract 10 µg/mL. NO production was determined by Griess method at 6, 12 and 24 h post-treatment. After each time point, 500µL of HBSS from the corresponding petri dish were recovered and processed as samples.

RESULTS AND DISCUSSION

Citotoxicity assay with the haemolytic activity model

The cytotoxicity assay of the *Castela texana* methanolic-extract showed hemolytic proportions of 4.52, 7.24 and 38.09% for the concentrations at 10, 100 and 1000 µg/mL, respectively. Based on these results, only the C*astela texana* extract at a concentration of 10 µg/mL was evaluated, since these results showed a cytotoxicity less than 5%, as shown in Figure 1.

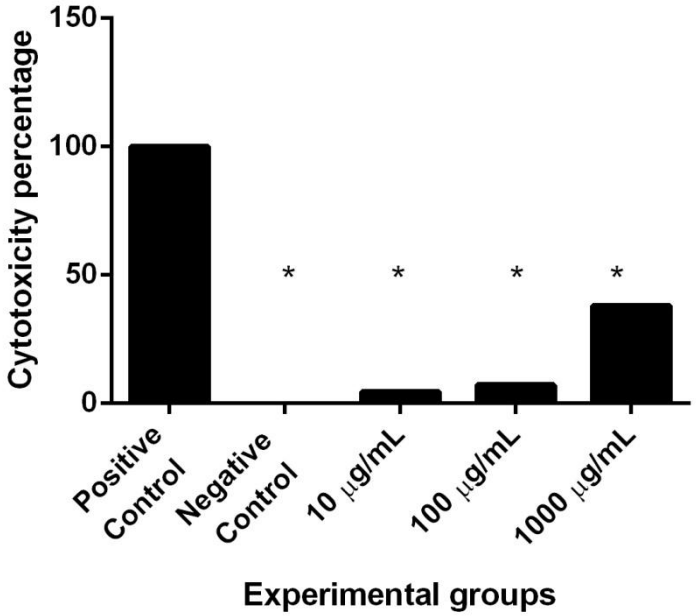


Figure 1. Citotoxicity assay with the haemolytic activity model. The experimental groups were prepared with *Castela texana* methanolic-extract at 10, 100 and 1000 µg/mL concentrations in saline solution; the positive and negative controls were distilled water and saline solution (0 µg/mL of the extract), respectively. *Statistically significant differences ($p < 0.05$).

NO quantification by the Griess method

According to the kinetics of nitric oxide production among experimental groups, no statistically significant differences ($p>0.05$) were observed between the baseline measurements (0 h) and the PBS negative control (6, 12 and 24 h); however, the differences between the positive controls and the *Castela texana* methanolic-extract group were statistically significant ($p<0.05$) in all time point determinations (6, 12 and 24 h), as shown in Figure 2.

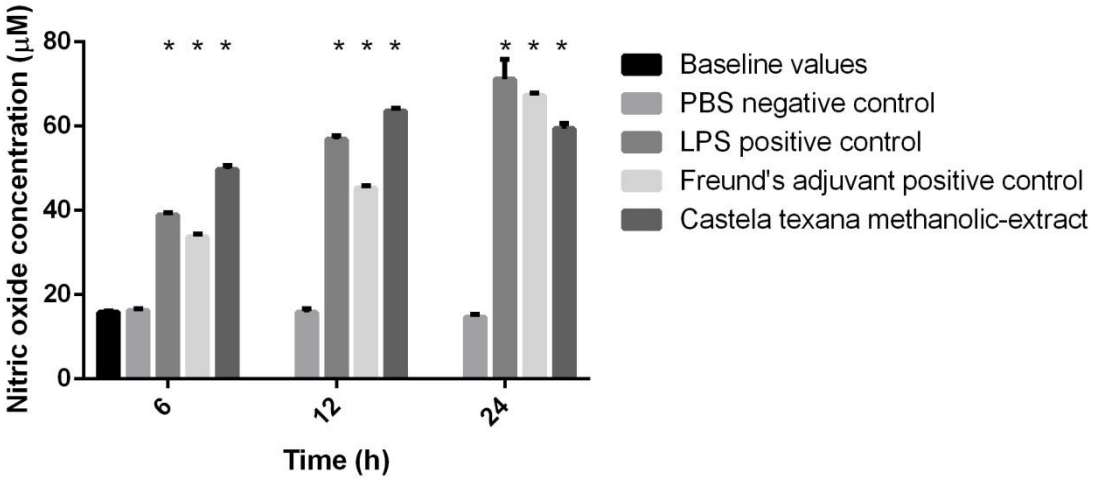


Figure 2. Nitric oxide quantification by the Griess method. Nitric oxide production was determined by nitrite quantification with Griess reagent at 6, 12 and 24 h post-infection. Values represent means and standard deviations from three experiments.*Statistically significant differences ($p < 0.05$).

The peritoneal cavity is an abdominal cavity of mammals that contains the liver, spleen, most of the gastrointestinal tract and other viscera. It hosts a series of immune cells, including macrophages, B and T lymphocytes. The presence of a high number of naïve macrophages in the peritoneal cavity makes it a good site for the collection of these cells reaching multiples of 1-2 x 10^6cells (Lu & Varley, 2008; Zhang *et al.*, 2010). However, the number of macrophages present in the peritoneum may be insufficient for an extensive experiment. Therefore, in this work, a thioglycollate solution was used as a stimulating agent to increase the migration of macrophages within the peritoneum, thus increasing performance and reaching multiples of up to 1 x 10^7cells (Hoover & Nancy, 1984).

Macrophages are a population of mononuclear phagocytes, present in almost all tissues; these cells are important regulators of inflammation and the innate immune response. They are dedicated to phagocytosis and therefore are effective in eliminating microbes and necrotic debris (Rico-Rosillo & Vega-Robledo, 2012). Macrophages secrete a large number of molecules that participate in the immune response (innate and adaptive) (Celada & Nathan, 1994; Hernández-Urzúa & Alvarado-Navarro, 2001). In the case of the innate immune response, molecules such as nitric oxide and reactive oxygen species can be mentioned; whereas, in the case of the adaptive immune response, various cytokines can be mentioned that lead to the polarization of the immune response towards a differential Th profile, thus favoring the optimal response of the host immune system (Cuellar *et al.*, 2010).

Some authors have reported that endotoxin levels around 0.5 ng/mL can significantly increase the production of cytokines and nitric oxide in peritoneal macrophages after only 6 hours of exposure (Herrera, 2014; Mac Micking *et al.*, 1997; Tamez *et al.*, 2001).The concentrations of endotoxin used in the control groups in this study were higher than this reference point (0.5 ng/mL) since, for example, each mL of Freund's complete adjuvant contains 1 mg of *Mycobacterium tuberculosis* (H37Ra, ATCC 25177), heat killed and dried, equivalent to an endotoxin concentration of 20 μg/mL in the positive control supplemented with 2% complete Freund's adjuvant.

Nitric oxide is a free radical in the gaseous state whose biological functions, in general, can be divided into two broad categories. First, NO acts as an intercellular messenger: by regulating vascular tone, activating platelets and acting as a neurotransmitter in the central nervous system. And second, when it is synthesized in large quantities by activated macrophages is a cytotoxic molecule involved in the elimination of bacteria, viruses and protozoa, as well as tumor cells (Gorocica *et al.*, 1999; López-Urrutia, 1999).

NO is synthesized from the amino acid L-arginine and molecular oxygen in a reaction catalyzed by nitric oxide synthetase (NOS). There are at least two types of NOS: 1) The calcium-dependent form that is constitutively present in a wide variety of tissues and produces physiological concentrations of NO. and 2) The calcium-independent form that is inducible by various immune stimuli such as interferon gamma (IFN ɣ), TNFα and bacterial lipopolysaccharide in various cell types such as macrophages, hepatocytes, neutrophils and endothelial cells. Once activated, these cells produce, for a long time, a large amount of NO in order to fight infectious agents (Abdala *et al.*, 2010; López-Urrutia, 1999). And for these reasons, the immunomodulatory activity of the

methanolic-extract of *Castela texana* leaf on the production of nitric oxide in murine peritoneal macrophages was evaluated. Since, as already mentioned, these cells are the major players of the first line of defense of the immune response, and the NO is synthesized as an immunomodulatory molecule in large quantities by activated macrophages.

CONCLUSION

The *Castela texana* methanolic-extract showed a high cytotoxic activity so only the lowest concentration at 10 µg/mL was evaluated on the production of nitric oxide in murine macrophages. The *Castela texana* extract triggered a high production of NO at short times (6 and 12 h) compared to the concentration of NO induced by the controls with LPS and complete Freund's adjuvant. However, at 24 h the induction of NO with the *Castela texana* extract began to decrease in contrast to the positive controls. Thus, it can be concluded that this extract may act as an acute activator of NO production in macrophages. Although in this work the molecular mechanisms involved were not elucidated, we believe that the phytochemical compounds of *Castela texana* could interact with molecules of the cell membrane, mimicking cellular activation signals. Therefore, this work represents an antecedent to study the use of *Castela texana* compounds as immunological adjuvants.

Conflict of Interest / Competing Interests

The authors declare no conflict of interest.

ACKNOWLEDGMENTS

The authors thank to the Consejo Nacional de Ciencia y Tecnología (CONACyT) for the scholarship given to HRRM in order to develop his graduate studies. To the program “Programa para el desarrollo professional docente, tipo superior” for supporting the Incorporation of NPTC (Dec 1st , 2017 -May 31st , 2019) for the grant with folio assigned to the professor UACOAH-PTC-442 and official number of the release letter 511- 6 / 17-13171.

REFERENCES

Abbas, A.K. and Lichtman, A.H. (2003). Métodos de estudio de la activación de linfocitos T, In: Inmunología celular y molecular. Spanish version of the 5th edn in English “Cellular and molecular immunology”, edited by Elsevier Science, (Madrid, España), 2003, 166-167.

Abdala-Díaz, R.T., Chabrillón M., Cabello-Pasini A., López-Soler B. and Figueroa, F.L. (2010). Efecto de los polisacáridos de Porphyridium cruentum sobre la actividad de la línea celular de macrófagos murinos RAW 264.7. *Ciencias marinas*. *36*(4):345-353.

Aliprantis, A.O., Diez-Roux, G., Mulder, L.C.F., Zylchlinsky, A. and Lang, R.A. (1996). Do macrophages kill through apoptosis?. Immunol. Today. 17: 573-576.

Calzado-Flores, Carmina Carlota y Verde Star, María Julia y Morales Vallarta, Mario R. and Segura Luna, José Juan (2007). Inhibición del proceso de enquistamiento de Entamoeba invadens por Castela texana. Ciencia UANL. 10 (1). ISSN 1405-9177.

Calzado-Flores C., Segura-Luna J.J. and Flores Villanueva Z. (1991). In vitro study of different antiamoebic drugs. Proc. West. Pharmacol. Soc. 34:355-8.

Calzado-Flores C. (1995). Cytotoxicity of Chaparrin from Castela texana. Proc. West. Pharmacol. Soc. 38:49-50.

Calzado-Flores C., Guajardo-Touche E.M., Carranza-Rosales M.P. and Segura-Luna J.J. (1998). In vitro anti-trichomonic activity of Castela texana. Proc. West. Pharmacol. Soc. 41:173-174.

Canell, D.S and Johnson, M.C. (1970). Manual of the Vascular Plants of Texas, Texas Research Foundation, Renner, Texas; 911:612.

Celada, A. and Nathan, C.F. (1994). Macrophage activation revisited. Immunol. Today. 15:100-102.

Cuellar Mata, P., Solís Martínez, M. O., Sánchez Leyva, Ma. C., García Niero, R.M. and Arias Negrete, S. (2010). El óxido nítrico: una molécula biológica llena de contrastes. Acta Universitaria, Universidad de Guanajuato. 20(3): 24-34.

González Stuart Armando (2019). Allthorn castela – Herbal safety. http://www.herbalsafety.utep.edu/herbal-fact-sheets/allthorn-castela/ (Accesed February 2019).

Gorocica, R. P., Chávez, S. R., Lascurain, L. R., Espinosa, M. B. and Zenteno, G. E. (1999). Óxido nítrico, una molécula multifuncional. Rev Inst Nal Enf Resp Mex. 12(4):300-304.

Herrera Lizzi (2014). Perfil del Macrófago I Biota et Scientia. https://biotaetscientia.com/2014/01/08/perfil-del-macrofago. (Accesed February 2019).

Hernández-Urúza Miguel, A. and Alvarado-Navarro, Anabell (2001). Interleucinas e inmunidad innata. Rev Biomed. 12(4):272-280.

Hoover, D.L. and Nancy, C.A. (1984). Macrophage activation to kill Lieshmania tropica: defective intracelular killing of amastigotes by macrophages elicited with sterile inflammatory agents. J. Immunol. 132(3):1487-93.

López-Urrutia Luis Lorente (1999). Inducción de la producción de óxido nítrico por lipopolisacárido de *Brucella* en macrófagos de rata. PhD thesis, (Universidad de Salamanca, Spain).

Lu, Mingfang and Varley Alan, W. (2008). Host Inactivation of bacteria lipopolysaccharides prevent prolonged tolerance following gram-negative

bacterial infection. Cell Host & Microbe, Elsevier inc. 4: 293-302.

Mac Micking, J., Xie, Q. and Natham, C. (1997). Nitric oxide and macrophage function. Annu Rev Immunol. 15: 323-350.

Mac Micking, J. D., North, R. J., La Course, R., Mudgett, J. S., Shah, S. K. and Nathan, C. F. (1997). Identification of nitric oxide synthase as a protective locus against tuberculosis. *Proceedings of the National Academy of Sciences of the United States of America*. *94*(10): 5243-8.

Martínez M. (1959). Las Plantas Medicinales de Mexico. 4a Ed. Ediciones Botas, México DF, 100.

Martínez, F. O. and Gordon, S. (2014). The M1 and M2 paradigm of macrophage activation: time for reassessment. Prime Rep. 6(13.10):12703.

Nathan, C.F. (1987). Secretory products of macrophages. J. Clin. Invest. 79: 319- 326.

Pedroza-Escobar, D. (2016). Analisis de conglomerado de variables de laboratorio en muestras biologicas de hombres que viven con VIH y sospecha de tuberculosis pulmonar, PhD thesis, (Instituto Politecnico Nacional, Mexico city).

Rico-Rosillo, María Guadalupe and Vega-Robledo, Gloria Bertha (2012). Nuevo rumbo en macrófagos, inflamación y tejido adiposo. Rev Med Inst Mex Seguro Soc. 50 (1): 39-45.

Riera Romo, M., Pérez-Martínez, D. and Castillo Ferrer, C. (2016). Innate immunity in vertebrates: an overview. *Immunology*. *148*(2):125-39.

Standley, P.C. (1923). Trees and Shrubs of México. NS Herbarium, Smithsonian Press, Washington, DC; 23:539.

Tamez, G. R. S., Rodríguez, P. C., Tamez, G. P. and Weber, J. R. (2001). Activación de macrófagos y linfocitos in vitro por extractos metanólicos en hojas de plantago major. Ciencia UANL. 4(3):304-313.

Uphof, J.C. (1968). Dictionary of Economic Plants. 5a Ed Verlag von J Cramer, Brasil. 113:339.

Zhang, M., Hanna, Michelle, Li, Jia, Butcher, Susan, Dai, Heping and Xiao, Wei (2010). Creation of a hyperpermeable yeast strain to genotoxic agents through combined inactivation of PDR and CWP genes. Toxicol Sci. 113(2):401-11.

RESEARCH ARTICLE

EVALUATION OF ADVANCE BREEDING LINES OF TUBEROSE (*POLIANTHES TUBEROSA* L.) FOR FLOWER YIELD AND QUALITY

T. Usha Bharathi* and R.Umamaheswari

ICAR-Indian Institute of Horticultural Research, Bengaluru-89
Email: t.ushabharathi@gmail.com

Received-07.12.2018, Revised-27.12.2018

Abstract: Three advance breeding lines 1x6-1, IIHR-12 and An sel-1 were evaluated for two consecutive years along with parents, local check and commercial check for flower yield and quality parameters. Advance breeding line IIHR-12 was found to be superior with better flowering and quality parameters such as the medium tall spike (72.64 cm), longest rachis (28.06 cm), extended flowering duration (190.80 days) number of matured bud on spike (5.31), shorter intermodal length (3.39 cm), low spike weight (54.87 g). IIHR-12 with straight spike buds with pink tinge and attractive star shaped flowers were found to be suitable as cut flower. It was also found to be field tolerant to root knot nematode *Meloidogyne incognita*. Advance breeding line 1 x6-1 was found to be superior to the commercial check Arka Prajwal for traits days to opening of first floret (22.07), flowering duration (185.67), weight of flower spike (79.24g) with straight spikes and flower buds with pink tinge. AN sel-1 has recorded to be superior than the commercial check Arka Prajwal for days to opening of first floret (21.70), number of florets per spike (55.17), diameter of floret (4.69 cm), flowering duration (207.41), number of spikes per clump (5.03). The nature of spike of AN sel-1 was found to be bent with pink tinge on flower buds. The commercial check Arka Prajwal registered superior performance for the traits matured bud weight (1.80g), single flower weight (2.29g) and hundred flower weight (221.04 g).

Keywords: Tuberose, Advance breeding lines, Evaluation, Flower yield, Quality

INTRODUCTION

Tuberose (*Polianthes tuberosa* Linn.) belongs to family *Asperagaceae* is an important bulbous flowering plant originated at Mexico (Bailey, 1919). The flowers of tuberose are used as a loose flower, cut flower and perfumery industry. It is cultivated India in an area of about 16.19 ('000 ha), with a loose flower production of 107.91 ('000 MT) and cut flower production of 89.29 (Lakh Nos.) of cut stems (Anon, 2016). In India it is commercially grown in West Bengal, Tamil Nadu, Andhra Pradesh, Karnataka, Odisha, Bihar, Chhattisgarh, Haryana, Madhya Pradesh, Maharastra, Telangana and Uttarakhand. Root knot nematode problems in tuberose are wide spread in North and South India (Rao *et al.* 2001). Wider occurrence of root knot nematode in the tuberose growing subtropical and tropical regions is reported to cause 10 to14 *per cent* reduction in flower yield (Khan and Parvatha Reddy, 1992). The crop has limited genetic variability due to self-incompatibility, dichogamy and poor seed setting (Shen *et al.*, 1986) resulting in very few improved cultivars. The present study was carried out with the aim to evaluate the advance breeding lines of tuberose lines developed at ICAR-IIHR, Bangalore for flower yield and quality.

MATERIALS AND METHODS

The experiment was conducted for two years during 2016 to 2018 in the research farm of division of Floriculture and Medicinal Crops, ICAR- Indian Institute of Horticultural Research), Bengaluru, India. The experimental site was geographically located at 13^{o} 58' N Latitude, 78^{o}E Longitude and at an elevation of 890 m above mean sea level. The following tuberose lines/cultivars were evaluated for their performance along with commercial and local check.

Tuberose lines/cultivars	Parentage	Type of flower
Hybrid 1x6-1	Arka Shringar x IIHR-6	Single
IIHR-12	Open pollinated seedling selection from Arka Shringar	Single
AN sel-1	Clonal selection from Arka Nirantara	Single
Arka Prajwal	Arka Shringar x Mexican Single	Single
Arka Nirantara	Arka Shringar x IIHR-6	Single
Mexican Single	Primitive Variety	Single
Arka Shringar	Mexican Single x 'Pearl' Double	Single
IIHR-6	Mexican Single x 'Pearl' Double	Single

*Corresponding Author

The experiment was laid out in randomized block design with three replications. Uniform size of bulbs (2.5 cm) were planted on raised bed with the spacing of 30 x 30 cm. Standard cultural practices were followed throughout the experiment period. The observations were recorded for two years on days to spike emergence, days to opening of first floret, spike length, rachis length, number of flowers per spike, length of floret, diameter of floret, bud length, matured bud weight, single flower weight, flowering duration, weight of 100 florets, number of spikes per clump, weight of florets per spike, number of bulbs per clump, number of bulblets per clump, internodal length and number of matured bud at a time. The tuberose lines/cultivars were screened for the tolerence/ resistance against root knot nematode *Meloidogyne incognita* for two years. Gall Index (GI) was recorded in a 0-5 scale as per Taylor and Sasser (1978). The pooled data of two years were statistically analysed as per Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Significant differences were recorded among the tuberose lines/cultivars evaluated for flowering parameters (Table 1 and 2). Days to spike emergence ranged from 112.37 (Arka Prajwal) to 152.23 days (IIHR-6) and none of the advance breeding lines were found to be superior to commercial check Arka Prajwal for this trait. Days to opening of first floret varied from 18.24 (Arka Shringar) to 28.00 days (IIHR-6) and this trait was recorded to be earliest in Arka Shringar (18.24). Early flowering in tuberose cv. Hyderabad Single was reported by Ramachandrudu and Thangam (2009) in cv. Mexican Single.

Spike length varied from 65.77 (Arka Shringar) to 115.63 cm (IIHR-6) and the tuberose lines IIHR-6 was found to be superior to the commercial check Arka Prajwal (91.77 cm). Spike length of IIHR-12 (72.64 cm) and Arka Shringar (65.77 cm) recorded to be medium tall and lesser than Arka Prajwal. Rachis length ranged from 17.28 (Mexican Single) to 28.06 cm (IIHR-12) and the cultivar IIHR-12 was found to be superior to the commercial check Arka Prajwal (25.78 cm). Number of florets per spike varied from 42.53 (IIHR-12) to 55.17 (AN sel-1) and the cultivars AN sel-1 (55.17), Arka Nirantara (51.90) and Arka Shringar (49.33). Variation in number of florets per spike was also assessed by Ranchana *et al.* (2013) in tuberose. Rani and Singh (2005) also reported similar variation in number of florets per spike in gladiolus.

Length of the floret ranged from 5.60 (IIHR-6) to 6.30 cm (Arka Nirantara) and it was found to be superior than the commercial check Arka Prajwal (6.08 cm) in the cultivars Arka Nirantara (6.30cm), AN sel-1 (6.27 cm) and IIHR-12 (6.02 cm). Krishnamoorthy *et al.* (2014) and Singh *et al*., (2018) also reported maximum floret length in variety Arka Prajwal. Diameter of the floret was found to be superior than the commercial check Arka Prajwal (4.31 cm) in Arka Nirantara (4.71 cm), AN sel-1 (4.69 cm) and Hybrid 1x6-1 (4.35 cm).This trait ranged from 3.67 (IIHR-12) to 4.71 cm (Arka Nirantara). The results are in close conformity with the findings of Mahawer *et al.* (2013), Singh and Dekho (2017) and Singh *et al*., (2018) in tuberose. The bud length varied from 5.39 (IIHR-6) to 6.20 cm (Mexican Single) and the cultivar Mexican Single found to be superior to the commercial check Arka Prajwal (6.11 cm). Matured bud weight ranged from 0.98 (IIHR-6) to 1.80 g (Arka Prajwal) and none of the cultivar was found to be superior over commercial check Arka Prajwal. The trait single flower weight varied from 1.31 (Mexican Single) to 2.29 g (Arka Prajwa) and none of the cultivars found to be superior to the commercial check Arka Prajwal. Weight of single floret is an important trait for loose flowers as they are sold on weight basis. Variation in weight of single floret might be due to the genetic makeup of the cultivars under study and similar observations were made by Ramachandrudu and Thangam (2009) in tuberose cultivar Arka Prajwal.

Flowering duration varied from 144.96 (IIHR-6) to 207.73 days (Arka Nirantara) and the cultivars Hybrid 1x6-1 (185.67), IIHR-12 (190.80), AN sel-1 (207.4) were found to be superior than the commercial check Arka Prajwal (181.88 days). Weight of hundred florets ranged from 119.53 (Mexican Single) to 221.04 g (Arka Prajwal) and none of the cultivars were found to be superior to the commercial check Arka Prajwal. The highest yield registered by Arka Prajwal might be due to its capacity to produce more number of flowers per spike and weight of florets per spike. The results are in corroborates with the findings of Krishnamoorthy *et al.* (2014), Vijayalaxmi and Lakshmidevamma (2016) in tuberose.

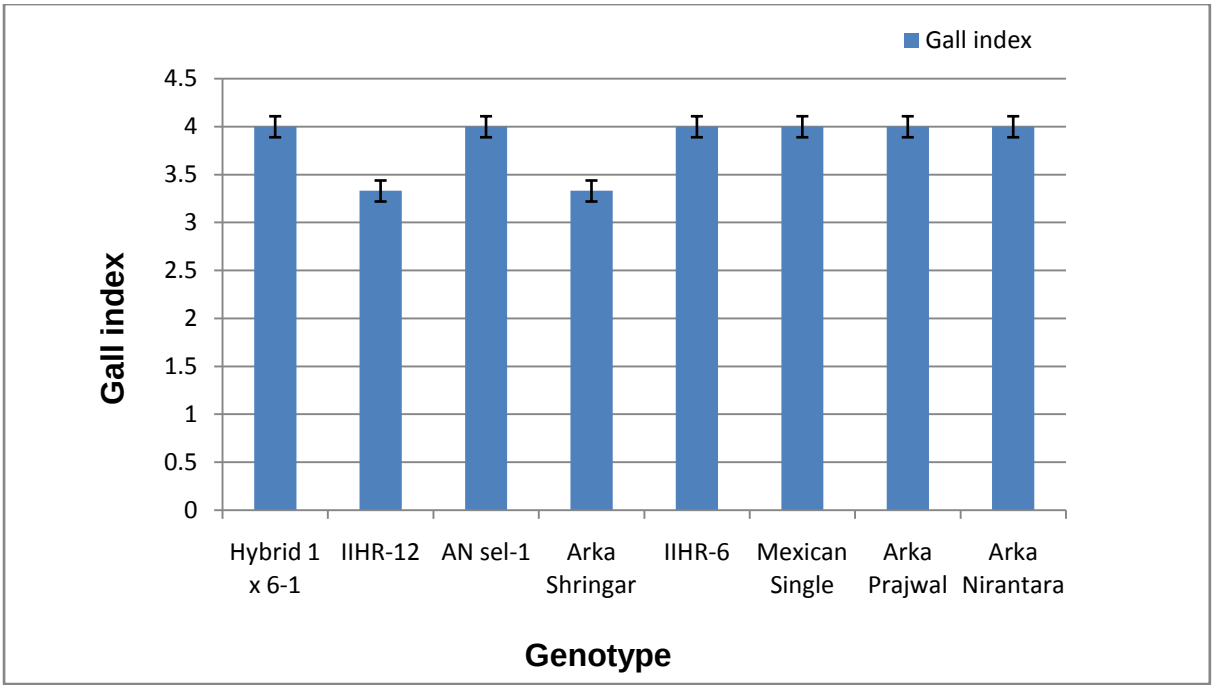
Number of spikes per clump varied from 2.07 (IIHR-6) to 5.41 (Arka Nirantara) and the cultivars Arka Nirantara (5.41) and AN sel-1 (5.03) were found to be superior than the commercial check Arka Prajwal. This variation in the production of spikes per clump might be due to the extended flowering duration, inherent genetic factor of different cultivars under prevailing environment condition. This variation in spikes per clump is in accordance with the findings of Martolia and Srivastava (2012) and Krishnamoorthy *et al.* (2014) in tuberose cv. Arka Prajwal.

The trait weight of florets per spike ranged from 43.37 (Mexican Single) to 79.24 g (Hybrid 1 x6-1) and the cultivar Hybrid 1 x 6-1 (79.24g) was found to be superior than the commercial check Arka Prajwal. The lesser spike weight is ideal for transportation of whole spike for cut flower purpose and the tuberose cultivars IIHR-12 (54.87 g), IIHR-6 (45.70 g) and Arka Shringar (43.45 g) registered lesser spike weight. Number of bulbs per clump varied from 2.92 (IIHR-12) to 8.25 (Arka Prajwal) and none of the cultivars were found to be superior than the commercial check Arka Prajwal. Similar observations were recorded by Martolia and Srivastava (2012) in tuberose.

The trait intermodal length indicates compactness of the florets arranged on rachis, which is ideal for cut flower. This trait varied from 3.39 (IIHR-12) to 5.65 cm (IIHR-6) and the cultivars IIHR-6 was found to be superior to the commercial check Arka Prajwal (5.24 cm). The tuberose cultivars IIHR-12 (Plate 1) recorded with shorter internodal length of 3.39 cm as like parent Arka Shringar (3.41 cm). Number of matured bud in spike depicts number of florets open at a time on spike which is the essential criteria for cut flower. This trait ranged from 2.05 (Mexican Single) to 5.31 (IIHR-12) and the cultivar IIHR-12 was found to be superior to the commercial check Arka Prajwal (3.20). Nature of spike of the cultivars Arka Prajwal, Hybrid 1 x6-1, IIHR-12, Arka Shringar were found to be straight. The nature of spike of cultivars Mexican Single and IIHR-6 were found to be slight bent and the cultivars Arka Nirantara and AN sel-1 were found to be bent. The tinge on flower bud wad recorded to be pink on all the tuberose cultivars under study except Mexican Single which was green in colour. The type of flower opening was found to be wide in all the cultivars except IIHR-12 which was shy opener with star shaped flowers. The tuberose lines and cultivars were screened for tolerance/resistance to root knort nematode (Fig 1). Among the lines/cultivars screened IIHR-12 and Arka Shringar are found to be tolerant to root knot nematode *Meloidogyne incognita*.

Plate 1. Advance breeding line of tuberose IIHR-12

Fig 1. Reaction of tuberose cultivars to root knot nematode



Gall index: 0-Immune, 1 - Highly resistant, 2 - Resistant, 3- Tolerant, 4- Susceptible, 5 - Highly Susceptible

Table 1. Flowering parameters of advance breeding lines of tuberose for the two years (2016-17 and 2017-18)

Genotype	Days to spike emergence	Days to opening of 1st floret	Spike length (cm)	Rachis length (cm)	Number of florets per spike	Length of Floret (cm)	Diameter of floret (cm)	Bud length (cm)	Matured bud weight (g)	Single flower weight (g)	Flowering duration (days)
Hybrid 1 x 6-1	114.07	22.07*	83.18	24.91	49.47	5.74	4.35	6.08	1.77	2.12	185.67*
IIHR-12	148.30	19.77*	72.64	28.06*	42.53	6.02	3.67	6.06	1.40	1.71	190.80*
AN sel-1	121.53	21.70*	89.48	23.40	55.17*	6.27	4.69*	5.98	1.21	1.58	207.41*
Arka Shringar	136.03	18.24*	65.77	19.77	49.33*	5.68	4.32	5.49	1.03	1.31	152.76
IIHR-6	152.53	28.00	115.93*	20.60	46.10	5.60	4.06	5.39	0.98	1.35	144.96
Mexican Single	130.60	20.30*	90.70	17.28	46.53	5.82	4.20	6.20*	0.98	1.20	160.44
Arka Prajwal	112.37	27.57	91.77	25.78	49.20	6.08	4.31	6.11	1.80	2.29	181.88
Arka Nirantara	117.80	21.70*	79.55	20.54	51.90*	6.30*	4.71*	6.08	1.26	1.54	207.73*
Mean	129.15	22.42	86.13	22.54	48.78	5.94	4.29	5.92	1.30	1.64	178.96
Range	112.37 - 152.53	18.24-27.57	65.77-115.93	17.28-28.06	42.53-55.17	5.60 - 6.30	3.67 - 4.71	5.39 - 6.20	0.98 - 1.80	1.31 - 2.29	144.96 - 207.73
CD(P=0.05)	4.89	1.91	5.07	2.46	4.00	0.45	0.22	0.20	0.16	0.22	9.05
CV %	2.16	4.86	3.36	6.24	4.69	4.35	2.99	1.94	6.77	7.54	2.89

* Superior than commercial check Arka Prajwal

Table 2. Flower yield and bulb parameters of advance breeding lines of tuberose for two years (2016-17 and 2017-18)

Genotype	Weight of hundred florets (g)	Number of spikes per clump	Weight of spike (g)	Number of bulbs per clump	Number of bulblets per clump	Internodal length (cm)	Number of matured bud at a time	Nature of spike	Tinge on flower bud	Type of flower opening
Hybrid 1 x 6-1	202.13	3.81	79.24*	3.92	35.50	4.80	3.73	Straight	Pink	Wide

IIHR-12	171.24	3.89	54.87	2.92	28.33	3.39	5.31*	Straight	Pink	Shy
AN sel-1	158.58	5.03*	64.75	7.00	38.08	4.51	2.32	Bent	Pink	Wide
Arka Shringar	134.31	3.40	43.45	3.92	40.92	3.41	2.12	Straight	Pink	Wide
IIHR-6	132.12	2.07	45.70	3.92	40.33	5.65*	2.95	Slight bent	Pink	Wide
Mexican Single	119.53	3.88	43.37	7.50	49.92	5.08	2.05	Slight bent	Green	Wide
Arka Prajwal	221.04	4.98	78.19	8.25	36.08	5.24	3.20	Straight	Pink	Wide
Arka Nirantara	153.57	5.41*	59.88	6.00	28.08	4.41	2.22	Bent	Pink	Wide
Mean	161.57	4.06	58.68	5.43	37.16	4.56	2.99	-	-	-
Range	119.53 - 221.04	2.07 - 5.41	43.37 - 79.24	2.92 - 8.25	28.33 - 49.92	3.39 - 5.65	2.05 - 5.31	-	-	-
CD(P=0.05)	11.37	0.34	11.57	1.32	NS	0.74	0.61	-	-	-
CV %	4.02	4.71	11.26	13.84	-	9.27	11.64	-	-	-

* Superior than commercial check Arka Prajwal

CONCLUSION

Among the cultivars evaluated for flowering and yield parameters, IIHR-12 with superior flowering and quality parameters such as the medium tall spike, longest rachis, more number of matured bud on spike, shorter intermodal length with compact flower arrangement were found to be suitable as cut flower. The low spike weight with straight spikes, buds with pink tinge and attractive novel star shaped flowers of IIHR-12 were also found to be ideal for cut flower. It was also found to be field tolerant to root knot nematode *Meloidogyne incognita*.

REFERENCES

Anonymous (2016). *Indian statistics*, Ministry of agricuture and farmers welfare, Government of India.

Bailey, L. H. (1919). The standard cyclopedia of horticulture. *Macmillan*, Vol. 2.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for Agricultural Research. John Wiley and Sons, New York.

Khan, R. M. and Parvatha Reddy, P. (1992). Nematode problems of ornamental crops and management. *Nematode pests of crops*.250-57.

Krishnamoorthy, V. (2014). Assessment of tuberose (*Polianthes tuberosa*) varieties for growth and yield characters.Asian Journal of Horticulture,9(2): 515-517.

Martolia, K. and Srivastava, R. (2012). Evaluation of different tuberose (*Polianthes tuberosa*) varieties for flowering attributes concrete and absolute content. *Indian J. Agric. Sci.* **88**: 170-80.

Ranchana, P., Kannan, M. and Jawaharlal, M. (2015). Evaluation of tuberose (*Polianthes tuberosa*) genotypes (double) for yield and genetic variability. Trends in Biosciences,8 (7): 1766 -1769.

Rani, R. and Singh, C. (2005). Evaluation of different gladiolus cultivars for quality flower production. *Journal of Research*, Bisra Agricultural University. 17(2):227-30.

Rao, M. S., Parvatha Reddy, P. and Wallia, R. K. (2001). Biological contro1 of nematodes in horticultural crops. National Nematology Congress-Centenary Celebrations, New Delhi, India.

Sateesha, G.R., Kumar, Anil and Biradar, M.S. (2011). Performance of different tuberose varieties under field conditions. *Plant Arch.* **11**: 359-60.

Shen, T. M., Huang, K. L. and Huang, T. S. (1986). Study of tuberose hybridization. In *Symp. Dev. New Floricult. Crops, XXII IHC,* 205: 71-74.

Singh, A.K. and Dakho, J. (2017). Evaluation on performance and superiority of tuberose (*Polianthes tuberosa* L.) cultivars for growth and flowering under North Indian plain. Environment and Ecology, 35 (1A): 341-345.

Singh, A., Singh, A.K., Sisodia, Anjana and Padhi, Minakshi (2018). Performance of Tuberose Varieties for Flowering and Flower Yield Parameters under Indo- gangetic Plains of Eastern Uttar Pradesh, India. Int.J.Curr.Microbiol.App.Sci (2018) 7(8): 1129 -1133.

Taylor, A. L. and Sasser, J. N. (1978). Biology, identification and control of root knot nematode *Meloidogyne spp*. North Carolina State Univeristy Graphics, Raleigh, NC, 111 pp.

Vijayalaxmi, G.P. and Lakshmidevamma, T.N. (2016). Evaluation of tuberose (*Polianthes tuberosa* L.) varieties for quality traits. Advances in Life Sciences, 5(12): 5370 -537.

RESEARCH ARTICLE

ESTIMATING GROWTH RATES AND DECOMPOSITION ANALYSIS OF MAJOR PULSES IN GUJARAT

Priyanka Changela and Ganga Devi*

Department of Agriculture Economics, B. A. College of Agriculture, Anand Agricultural University, Anand - 388 110, Gujarat, India
Email: gangasaran1982@gmail.com

Received-02.12.2018, Revised-22.12.2018

Abstract: India is known for the world's largest pulses sector, producing and consuming diversity of pulses. This paper explores the trend in area, production and productivity of major pulse crops *i.e.* chickpea and pigeon pea grown in Gujarat as well as India. The results showed that the CGRs of area, production and yield over sixteen years (2001-02 to 2016-17) were positive and significant for total pulses in India while, in Gujarat production and yield was increased significantly. Further it was observed that the CGR of area, production and yield of chickpea was positive and significant, whereas in case of pigeon pea the CGR of production and yield was positive and significant in Gujarat. The decomposition analysis concluded that increasing area of chickpea, pigeon pea and total pulse play an important role in increasing production of these crops in India but in Gujarat increasing in yield was increased total production of pulses. Import of total pulses was higher than export of total pulses with 10.48 per cent CGR in India during last twelve years. Whereas, chickpea contribute higher proportion for both total export and import in India. To meet the growing requirement, the country has to produce an adequate amount of pulses as well as remain competitive to keep the domestic production. Overall performance of pulse crops was quite impressive which can be seen by positive growth rate and reduced instability, which is good sign for sustainable agriculture and regional food security.

Keyword: Pulses, Compound growth rate, Instability index, Decomposition analysis, Export, Import

INTRODUCTION

Pulses are an important commodity group of crops that provide high quality protein complementing cereal proteins for pre-dominantly substantial vegetarian population of the country. The results from household consumption surveys indicate decline in the consumption of pulses leading to increase in malnutrition and decline in protein intake, about 15.2% of people in India are undernourished (Shalendra *et al*., 2013). Consumption of pulses is one of the solutions to achieve a problem of poor nutrition and zero hunger under as part of the Sustainable Development Goals (SDGs). In India, pulses grown in 24-25 million hectares of the area with annual production of 17-18 million tonnes. India is the largest producer with 25 per cent of global production, importer with 14 per cent and consumer with 27 per cent at global production (Mohanty and Satyasai, 2015). India is the largest producer of chickpea and pigeon pea with 67.5 and 63.7% of share in global production, respectively. Demand for pulses in India was 21 million tonnes as compared to production of pulses was only 16.35 million tonnes during 2015-16 (DAC&FW, 2016). Even being the largest producer of pulses, the persistent and growing demand–supply gap has been an issue of concern leading to spike in prices further resulting in this good source of vegetarian protein inaccessible to the poor.

Gujarat state is categorized as one of the minor pulse producing state in India (Srivastava, *et al*., 2010). In recent time, state is in limelight as agriculture has recorded fastest growth *i.e.* 9.6 per cent during the year 2000 to 2010 among all Indian state. (Gulati, *et al.,* 2009). In India, total pulse area and production irrespective of Twelfth Plan was 252.43 lakh hectares and 187.00 lakh tonnes respectively. Out of the total area and production Gujarat have only 2.85 and 3.47 per cent of area and production, respectively but in case of productivity of pulses Gujarat have 5th rank (902 kg per ha). However, 2nd and 3rd rank for productivity of pigeon pea and chickpea, respectively (DAC&FW, 2016). Looking to the productivity scenario of pulses, Gujarat has great potential and scope to expand the area and meet the gap between demand and supply with enormous extent. Keeping this in view the present study was planned with the objective of estimating growth trend in area, production, productivity, export, import and decomposition analysis at Gujarat as well as India to compare the state performance at country level.

METHODOLOGY

The secondary data on area, production and yield of pulses were compiled from the Indian Institute of Pulse Research Station, Kanpur and annual report of government of India for the period 2001-02 to 2016-17. The data related to export and import of pulse for the period of 2005-06 to 2016-17 were compiled from Directorate General of Commercial Intelligence and Statistics, government of India. The collected data were compiled and analyzed using following statistical tools.

The compound growth rate (CGR) and Instability Index (II) was calculated by fitting the exponential function given below:

*Corresponding Author

$$Y = a\, b^t$$

Where, Y= area/production/yield
a = constant
b = regression co-efficient
t= time variable

The simple co-efficient of variation (CV) often contains the trend component and thus over estimates the level of instability in time series data characterized by long-term trends. To overcome this problem, the Cuddy Della Valle Index was used which corrects the CV.

Instability Index (II) = CV x $\sqrt{(1-R^2)}$

Where, CV = co-efficient of variation and

R^2 = co-efficient of determination from a time trend regression adjusted by the number of degrees of freedom.

Decomposition Analysis

To measure the relative contribution of area and yield towards the total production. The decomposition analysis suggested by Minhas & Vidhyanathan (1965) redeveloped by Sharma (1977) was used. The change in production was taken as the effect of three factors such as yield effect, area effect and interaction effect.

$\Delta P = A_b * \Delta Y + Y_b * \Delta A + \Delta A * \Delta Y$

ΔP = Change in production

A_b= Area in base year

Y_b = Yield in the base year

Y_c = Yield in the current year

A_c = Area in the current year

ΔA = Change in area (A_c-A_b)

ΔY = Change in the yield ($Y_c - Y_b$)

Change in production = Yield effect + Area effect + Interaction effect.

Thus, the total changes in production was decomposed in to three effects *viz*, yield effect, area effect and interaction effect due to change in yield and area.

(Base Year = Average of triennium end 2001-03)

RESULTS AND DISCUSSION

Total pulses

Compound growth rate (CGRs) and Instability Index (II) of area, production and yield of pulses crop in Gujarat and India were computed and presented in Table 1.

It is revealed from table that the growth rate of area was found negatively non-significant for total pulses in Gujarat (-0.56 per cent), whereas in India it was positive and significant (1.90 per cent). This showed that area of pulses in Gujarat has decreased non-significantly from last sixteen years but area of pulses at central level was increased significantly. Further the results indicated that the growth rate of production (2.26 per cent and 3.32 per cent) and yield (3.18 per cent and 1.51 per cent) was positive and significant in Gujarat as well as in India, respectively. This clearly showed that production and yield of pulses was increased significantly in Gujarat and India over the years. Similar findings were also reported by Latika, *et al*. (2017) in India.

Table 1. Compound growth rate (CGR) and Instability Index (II) of area, production and yield of total pulses (2001-02 to 2016-17).

Particular	Gujarat		India	
	CGR (%)	II	CGR (%)	II
Area	-0.56 (0.0042)	15.21	1.90** (0.0018)	8.05
Production	2.26* (0.0054)	20.45	3.32** (0.0020)	8.46
Yield	3.18** (0.0030)	11.27	1.51** (0.0012)	4.72

* Significant at 5 per cent level; ** Significant at 1 per cent level
Figure in the parenthesis are standard errors.

Further, the result showed that Instability Index (II) of area was varied from 8.05 (India) to 15.21 (Gujarat) and for production it was varied from 8.46 (India) to 20.45 (Gujarat). In case of yield it was varied from 4.72 (India) to 11.27 (Gujarat) in last sixteen years. This clearly indicated that variability in area, production and yield of total pulses in Gujarat was higher than India.

Chickpea

The state and national level performance of chickpea crop during last sixteen years represented in Table 2. The CGR of area, production and yield was found positive and significant for chickpea in Gujarat which was 3.08, 6.91 and 3.51 per cent, respectively. At country level the CGR of area, production and yield was also found positive and significant with 2.75, 4.41 and 1.59 per cent, respectively. This showed that the area, production and yield of chickpea increased significantly in Gujarat as well as in India but the higher growth rate was found in Gujarat.

Table 2. Compound growth rate (CGR) and Instability Index (II) of area, production and yield of chickpea (2001-02 to 2016-17).

Particular	Gujarat		India	
	CGR (%)	II	CGR (%)	II
Area	3.08* (0.0094)	33.89	2.75** (0.0018)	7.01
Production	6.91** (0.0132)	41.41	4.41** (0.0031)	11.55
Yield	3.51** (0.0042)	15.65	1.59** (0.0017)	6.35

* Significant at 5 per cent level; ** Significant at 1 per cent level
Figure in the parenthesis are standard errors.

Further the results of Instability Index (II) of chickpea showed that the highest instability index was found for production (41.41) followed by area (33.89) and yield (15.65) in Gujarat. Whereas it was highest in production (11.55) followed by area (7.01) and yield (6.35) at country level. This clearly indicated that the variability in area, production and yield of chickpea was high in Gujarat as compared to India as yield was more stable as compared to area and production at both levels.

Pigeon pea

Compound growth rate (CGRs) and Instability Index (II) of area, production and yield of pigeon pea crop in Gujarat and India were computed and presented in Table 3. The CGR of area for pigeon pea crop was negatively non-significant in Gujarat (-1.47 per cent), whereas, positive and significant in India (1.97 per cent). This indicated that area of pigeon pea increased significantly in India but decreased in Gujarat. The reduction in area of pigeon pea in recent years was also reported by More *et. al.,* 2015. While, growth rate of production (1.87 per cent and 2.94 per cent) was positive and significant in Gujarat as well as in India, respectively. In case of yield (2.96 per cent) the positive and significant growth rate was found in Gujarat, whereas at country level it was positively non significant. It can be concluded that production and yield of pigeon pea was increased significantly in Gujarat but in India only production increased significantly.

Further, the result revealed that Instability Index (II) of area was varied from 9.36 (India) to 13.53 (Gujarat) and for production it was varied from 16.66 (Gujarat) to 17.03 (India). In case of yield it was varied from 9.58 (India) to 13.80 (Gujarat). The results revealed that variability in area and yield of pigeon pea in Gujarat was higher as compared to India.

Table 3. Compound growth rate (CGR) and Instability Index (II) of area, production and yield of pigeon pea (2001-02 to 2016-17).

Particular	Gujarat		India	
	CGR (%)	II	CGR (%)	II
Area	-1.04 (0.0033)	13.53	1.97** (0.0022)	9.36
Production	1.87* (0.0039)	16.66	2.96** (0.0039)	17.03
Yield	2.94** (0.0033)	13.80	0.95 (0.0025)	9.58

* Significant at 5 per cent level; ** Significant at 1 per cent level
Figure in the parenthesis are standard errors.

Decomposition Analysis

To know the percentage contribution of area and yield in increasing production of chickpea, pigeon pea and total pulses, decomposition analysis was carried out and presented in Table 4. The results put forth that all three effects are positive for chickpea, pigeon pea and total pulses in Gujarat as well as in India during 2001-02 to 2016-17. This clearly indicated that area, yield and their interaction effects contributed positively in increasing production of pulses at state and country level. However, in Gujarat yield effect was playing important role for increasing chickpea, pigeon pea and total pulses production with 34.61, 63.31 and 63.97 per cent, respectively. Whereas in India, area effect contributes important role in increasing production of chickpea, pigeon pea and total pulses production with 65.00, 62.56 and 62.51 per cent, respectively. This revealed that increasing yield of pulse crops was contributing more in increasing pulse production in Gujarat as compared to area and their interaction effects, while at country level area effect contributing more in production as compared to yield and their interaction effects.

Table 4. Decomposition analysis of area, yield and their interaction towards increasing production of pulses (2001-02 to 2016-17)

Particular	Gujarat			India		
	Chickpea	Pigeon pea	Total pulses	Chickpea	Pigeon pea	Total pulses
Yield effect	34.61	63.31	63.97	33.01	34.70	35.14
Area effect	60.30	33.99	33.86	65.00	62.56	62.51
Interaction effect	5.07	2.69	2.15	1.98	2.72	2.33

Export and import of pulses

The increasing mismatch between production and consumption of pulses has resulted in larger imports of pulses in recent years. The growth rate of export and import of pulses was expressed in Table 5. The CGR of export and import of total pulses in India was 2.21 and 10.48 per cent, respectively during 2005-06 to 2016-17. This clearly shows that import was increased significantly than export in India.

Table 5. Compound growth rate of export and import of pulses in India (2005-06 to 2016-17).

Particular	Export		Import	
Year	Quantity (q)	Value (Rs. Crore)	Quantity (q)	Value (Rs. Crore)
2005	4516261	1124.66	16956500	2476.25
2006	2550845	789.99	22070070	3782.81
2007	1706144	549.01	27888150	5,288.00
2008	1368801	542.32	26232190	6,469.00
2009	1001309	408.32	37499880	10629.16
2010	2090105	870.04	27778270	7512.49
2011	1746252	1067.93	34958420	9448.35
2012	2027514	1285.00	40132360	13344.63
2013	3452767	1747.63	31778920	11036.75
2014	2222621	1219.08	45848520	17062.94
2015	2560519	1658.09	57977060	25619.06
2016	1369680	1278.79	66089510	28523.9
CGR (%)	2.21* (0.0148)	12.09** (0.0128)	10.48** (0.0057)	19.90** (0.0079)

* Significant at 5 per cent level; ** Significant at 1 per cent level

Source: DGCIS, GOI.

Export of chickpea was decreased in quantity as well as in value terms during 2015 to 2017, whereas in case of pigeon pea the export was increased in quantity (40,258.8 qtl to 1,05,419.98 qtl) as well as in value (Rs. 52.55 Crore to Rs. 78.36 Crore) terms. Further, the export of chickpea was higher than export of pigeon pea and other pulses (Table 6). However, the import of chickpea was higher than import of pigeon pea in India.

Table 6. Export and import of chickpea and pigeon pea (2015-16 to 2017-18).

Particular	Export		Import	
	Chickpea			
Year	Quantity (q)	Value (Rs. Crore)	Quantity (q)	Value (Rs. Crore)
2015	21,70,564.01	1337.64	10,31,486.66	4453.71
2016	8,75,089.63	841.41	10,80,633.37	6106.77
2017	12,79,195.87	1121.37	9,81,316.34	5437.85
	Pigeon pea			
2015	40,258.80	52.55	4,62,713.00	3318.22
2016	1,23,025.64	141.54	7,03,543.76	4091.48
2017	1,05,419.98	78.36	4,12,952.99	1416.99

Source: DGCIS, GOI.

CONCLUSION

Pulses are major source of protein for a huge population particularly vegetarian population. Chickpea and pigeon pea are major pulse crops widely grown in Gujarat as well as in country. The results showed that the CGRs of area, production and yield over the years were positive and significant for

total pulses in India while, in Gujarat production and yield was increased significantly. Further it was observed that the CGR of area, production and yield of chickpea was positive and significant, whereas in case of pigeon pea the CGR of production and yield was positive and significant in Gujarat. Decomposition analysis concluded that increasing area of chickpea, pigeon pea and total pulse play an important role in increasing production of pulse crops in India but in Gujarat increasing in yield was contributed more in increased total production of pulses. The CGR of import was found more as compared to export of pulses in India. This clearly shows that import was increased significantly than export in India due to the huge demand. The Overall performance of pulse crops was quite impressive which can be seen by positive growth rate and reduced instability, which is eye catching for policy makers and good sign for regional food security and showing the potential of pulse crops.

REFERENCES

Annual Report (2016). Directorate of Pulses Development. Department of Agriculture, Cooperation & Farmers Welfare, Government of India, New Delhi.

Directorate General of Commercial Intelligence and Statistics (DGCIS), Government of India. Retrieved from *www.dgciskol.gov.in.*

Indian Institute of Pulse Research Station, Kanpur. E-pulse book. Retrieved from *iipr.res.in/pulse-data-book.html*

Gulati, A., Shah, T. and Ganga, S. (2009). *Agriculture Performance in Gujarat since 2000: Can it be a Divadandi for other State?* New Delhi: International Food Policy Research Institute.

Latika, Y. D., Arivelarasan, T. and Kapngaihlian, J. (2017). Pulses production in India: trend and decomposition analysis. *Economic Affairs*, **62**(3), 435-438.

Minhas, B. S. and Vaidynathan, A. (1965). Growth of crop output in India. *Journal of Indian Society of Agricultural Statistics,* **28**(2), 230-252.

Mohanty, S. and Satyasai, K. J. (2015). "Feeling the pulse, Indian pulses sector." NABARD rural pulse, **10**, 1-4.

More, S. S., Singh, N. and Kuthe, S. B. (2015). Performance of pulses crops in Gujarat state - a Decomposition Analysis. *International Journal of Agriculture Sciences,* **7**(5), 510–515.

Shalendra, Gummagolmath, K. C., Sharma, P. and Patil, S. M. (2013). Role of pulses in the food and nutritional security in India. *Journal of Food Legumes*, **26**, 124–129.

Sharma, K. L. (1977). Measurement of the area, yield and prices in the increase value of crop output in India. *Agriculture Situation in India*, **32**(6), 349-351.

Srivastava, S. K., Sivaramane, N. and Mathur, V. C. (2010). Diagnosis of pulses performance of. India. *Agricultural Economics Research Review*, **23**(1), 137-148.

RESEARCH ARTICLE

UTILIZATION OF WINTER HABIT DONOR, *AEGILOPS TAUSCHII* BY VERNALIZATION AND PHOTOPERIOD MANAGEMENT

Cambay, S.R.*, Sandhu, S.K.,[1] Srivastava, P.,[1] Rana, M.,[2] and Bains, N.S.[1]

Division of Genetics, IARI, New Delhi, 110012
[1]Department of Plant Breeding & Genetics, PAU, Ludhiana, 141012
[2]Division of Crop Improvement, IGFRI, Jhansi, 284128

Received-05.12.2018, Revised-26.12.2018

Abstract: Allelic diversity in the wild grass Aegilops tauschii is vastly greater than that in the D genome of common wheat. Numerous efforts have been made to harness this extensive and highly variable gene pool for wheat improvement. This follows two distinct approaches, first production of amphiploids, between *Triticum turgidum* and *Aegilops tauschii*, and second direct hybridization between *Aegilops tauschii* and *Triticum aestivum*; both approaches then involve backcrossing to *Triticum aestivum*. Long duration, winter habit and specific requirements for raising *Aegilops tauschii* often make it difficult for every breeder to utilize the resource in their breeding programme. We demonstrate an easy low cost protocol for raising *Aegilops tauschii*, three times a year to facilitate the hybridization programs.

Keywords: Growth chamber, Faster breeding, Hybridization, Low cost

INTRODUCTION

Wheat breeding requires constant input of variation to attain higher yield. Owing to its own narrow genetic base, its progenitor and non progenitor species can be tapped to enhance the available variation. Among these, *Aegilops tauschii* Coss. commonaly known as goat grass is a wild diploid wheat relative and contributes the D genome to wheat (Kihara, 1944; McFadden and Sears, 1946). Wheat lines derived from those crosses have since been used in breeding programs worldwide and have helped farmers to boost yields by up to 20 percent. Goat grass is known for being highly adaptable and disease tolerant, so the crosses endow wheat with similar qualities. Varieties from these crosses make up over 30 percent of international seed stores (Rasheed *et al*., 2018). The D genome of *Ae. tauschii* was brought into the allohexaploid genome of common wheat through interspecific crossing to tetraploid wheat and subsequent amphidiploidization about 8000 years ago (Matsuoka, 2011). In contrast to the narrow geographic distribution of the other progenitor species, *Ae. tauschii* extends over a wide geographic range from eastern Turkey to China.

The fact that diploid D genome progenitor possesses a higher genetic diversity compared to bread wheat cultivars and landraces (Reif *et al*., 2005) makes it an ideal target for tapping novel genetic variation. *Ae. tauschii* has been used to introgress specific traits that include diverse resistance genes (Olson *et al*., 2013; Mandeep *et al*., 2010; Leonova *et al*., 2007; Miranda *et al*., 2006; Ma *et al*., 1993; Eastwood *et al*. ,1994), bread-making quality (Li *et al*., 2012), pre-harvest sprouting tolerance (Gatford *et al*., 2002; Imtiaz *et al*., 2008), yield (Gororo *et al*., 2002) and also morphological characters (Watanabe *et al*., 2006) into breeding material and cultivars of bread wheat.

Since the mid-twentieth century efforts directed at creating *Ae tauschii* introgressions into wheat has come from two avenues. Firstly, the more common approach of artificial hexaploid wheat synthesis that is generated by crossing tetraploid wheat with *Ae tauschii* and then doubling the triploid chromosome set by colchicine treatment or spontaneous doubling arising from unreduced gamete formation. Numerous reports on synthetic hexaploids have been reviewed by Ogbonnaya *et al*., (2013). Secondly, the process of direct introgression which involves *Ae tauschii* crosses with bread wheat where *Ae. tauschii* is the female parent and hexaploid as the male parent. The F_1 is either subjected to chromosome doubling and later backcrossed or is directly backcrossed repeatedly to recover a stable bread wheat derivative (Gill and Raupp, 1987). In this appraoach recombinant chromosomes between the diploid and hexaploid D genomes are produced. Introgression approaches that occur via synthetic hexaploids are not limited to the D genome but also involve the A and B genomes. As an alternative approach, wheat chromosome substitution lines carrying different chromosomes of *Ae. tauschii* were used in generating a set of well-characterized *Trtitcum aestivum/Ae. tauschii* introgression lines (Pestsova *et al*., 2006; Law and Worland, 1973).

MATERIALS AND METHODS

The production of synthetic wheat require hybridization which is simple and follows emasculation of durum wheat as female parent and *Ae. tauschii* is used as male parent for pollinations. Repeat pollination can be done or multiple spikes of tauschii can be used to ensure fertilization and seed set. Staggered planting or atleast three sowings of

*Corresponding Author

durums at regular intervals may be done, so that their flowering coincides with the flowering of the *Ae. tauschii* accessions. The F_1 seed set on durum wheat is observed and recorded. The F_1s are planted, these can be given chromosome doubling treatment to form stable synthetic wheat. Spontaneous doubling also occurs to some extent and can give stable synthetic hexaploid wheat.

In direct cross technique, the tauschii is taken as female parent and hexaploid wheat as male parent, post pollination support of auxin hormome like 2,4-D is given at 125 ppm concentration either as spray or drops to florets. In this cross, endosperm dose not form and developing hybrid embryo needs to be rescued and cultured over artificial medium. Post regeneration, the developing seedlings are hardened and given chromosome doubling treatment. On success of chromosome doubling, formation of octaploid will occur and these are fertile and can be utilized in backcross programme with hexaploid wheat, else the haploid ABDD can be backcrossed with hexaploid and some seed can be obtained which is again backcrossed for restoration of complete fertility.

RESULTS AND DISCUSSION

Direct crossing of *Ae. tauschii* with bread wheat is said to be the most ideal, efficient technique for exploiting Ae. tauschii variability for bread wheat improvement as this methodology rapidly produces improved BC_1. Alonso and Kimber., (1984); Cox *et al*., (1990,1991) and Gill and Raupp, (1987) unequivocally placed priority on crossing *Ae. tauschii* directly with bread wheat cultivars. Based on the transfer of stem rust resistance from *Ae. tauschii* to the bread wheat cultivar, Chinese Spring, Alonso and Kimber, (1984) determined that one backcross on to the F_l hybrids restored 92% of the genotype of the recurrent parent. In addition, the slight genotypic specificity seen in production of synthetic wheat, is ruled out here as any desirable wheat genotype can be used as the male parent e.g., 'Ciano T 79', 'Kanchan', 'Seri M 82','Opata M 85', 'Oasis F 86' and 'PBW 343' etc have been reportedly used for transfer of various traits (Mujeeb-Kazi *et al*., 2006). Recently, the role of *Ae. tauschii* in drought and heat tolerance along with contribution towards yield components was established by work done at PAU (Chuneja, 2017; Arora *et al*., 2017). For transferring these traits, raising of tauschii was initiated and present study elaborates the protocol followed to raise the wild species multiple times a years to facilitate large number of crosses.

The basic requirement for conducting such crosses is raising of *Ae. tauschii*, a winter habit wild species along with durum wheat or bread wheat. Multiple sowing of durum and bread wheat is done so as to synchronize the flowering. *Ae. tauschii* when grown in normal conditions without vernalization, flowers when wheat season is almost over(Table 1). The number of ears and florets are less and often cleistogamous nature gets promoted owing to high temperature in the field. This renders it unsuitable for crossing; in addition wheat can be available only if raised in greenhouses and/or growth chambers. The synchronisation and timely flowering in *Ae. tauschii* can be instigated through specific measures. Vernalization treatment and photoperiod extension are two ways through which the flowering time manipulation can take place in *Ae. tauschii*. Most breeders utilizing tauschii provide it mostly extended photoperiod and go for staggered or multiple sowing of wheat or durum parents under controlled conditions. This provides single opportunity for conducting crosses. Though its an established fact that vernalization and photoperiod are basic requirement for winter habit genotypes, and should be given but no clear protocol is available for the same. We hereby present a standardized protocol for raising Ae. tauschii multiple times a year as per requirement. The partial controlled facility and largely field based protocol can be utilised by wheat groups working in Northern India.

Three distinct growing seasons have been identified, First, September to May, this is parallel to the main wheat season in north India and crossing can be undertaken during month of February and March. Second, growing tauschii at off season location Keylong (10500ft altitude, Himanchal Pradesh), (April to October) and flowering occurs in the month of July and third is early planting at Ludhiana where flowering occurs in November. All the three system require vernalization but extended photoperiod is not required in later two approaches. The vernalization treatment is given through simple domestic refrigerators for 6 weeks at 4^0C followed by fixation of the treatment at 15^0C in growth chambers for 12-15 days. The exposure to light is not made during 6 weeks of vernalization, as than we need to shift to growth chambers with lights and this leads to rising of temperature under light. Precise controlled conditions are required for temperature, in absence of which the treatment is not effective. During vernalization the seeds are frequently watered with ¼ MS solution. The moisture should be maintained but over watering and complete wet situation should be avoided. If some fungal infection is observed, use of carbendazim (wettable powder) is done to control the fungus. The treatment in simple refrigerators is effective and anyone can duplicate the same. The fixation is not required, when growing tauschii at offseason as field temperatures are already lower than required temperature at off season location. Further for utilizing the space and number of accessions specific measure like growing the seeds in petriplates (Fig 1 B) and germination paper bags

(Fig 1 C) as against small trays (Fig 1A) is recommended. The vernalization using petriplates also helps in easy transportation of the samples to other locations, in our case Off season at Keylong. Since the road passage is closed until May, the vernalization is initiated in April and 6 weeks later petriplates are carried to the off season location without damaging the vernalized seedlings.

Table 1. Comparison of *Ae. tauschii* growing periods in Ludhiana and Keylong

Duration	Time of flowering	Vernalization	Photoperiod	No of tillers	Suitability
September to May	Feb-March 170-180 days	6 weeks (Refrigerator) 2 weeks fixation (Growth chamber)	December-January	>50 6-8 florets	++
April to October	July 90-100 days	6 weeks (Refrigerator) 2 weeks fixation not required	Not required	30-50 More no. of florets (~12)	++++
July to February	November 120-130 days	6 weeks (Refrigerator) 2weeks fixation (growth chamber)	Not required	30-40 More number of florets (~12)	+
October-June (control)	April-May >190 days	Not given	Not given	Few tillers and florets	-

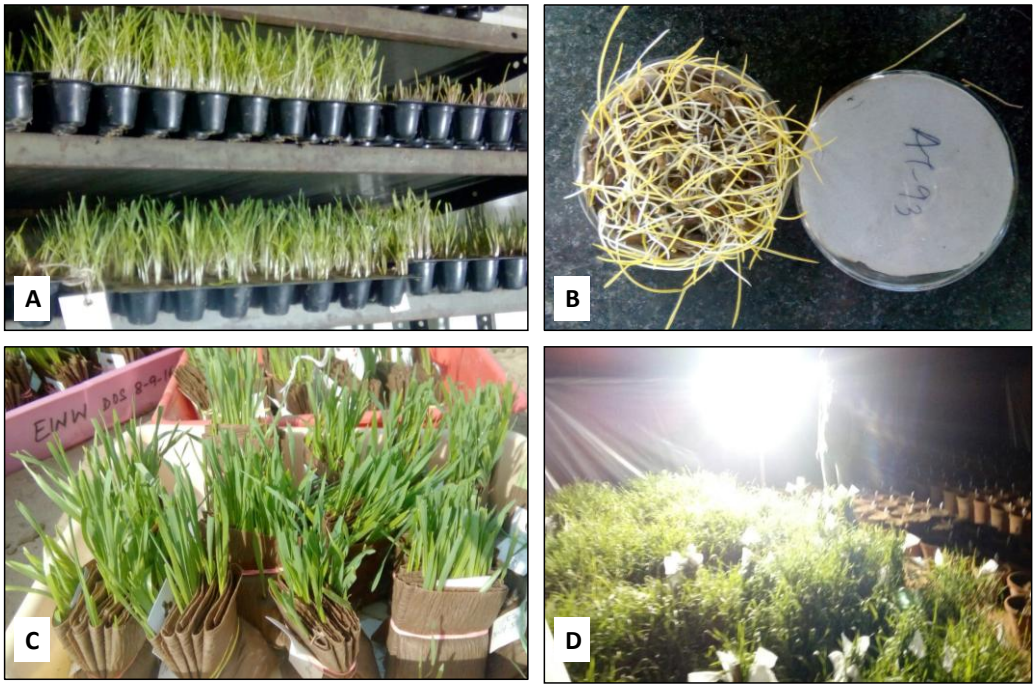


Figure 1: A) Vernalization and fixation of vernalization in plastic propagation tray B) Vernalization treatment in petriplates C) Vernalization treatment in germination paper pouches D) Extended photoperiod through use of halogen and/or LED lamps

Post vernalization and fixation, the seedlings are transferred to field. Pulverised soil bed is enriched with vermi-compost and standard dose of nitrogen, phosphorus and potash is provided. If possible soil application of zinc and sulphur can also be made for complete nutrition. Seedlings are regularly watered to promote establishment. The extension in photoperiod is provided through use of Halogen lamps (400 watt) and/or LED (50 watt) lamps (Fig 1 D) under filed conditions. The photoperiod is continued till flowering in initiated and once the accessions start showing the ears, the lamps can be removed. The tillering and ear size and floret number may vary (Table 1) but still is sufficient to conduct the crossing under any of the three situations against the control treatment. The

comparison of three growing season shows that raising tauschii at off season location is best treatment as it requires less resources and time. Also the, flowering is quite determinate in nature over there, in addition it provides the next season in tandem to carry out chromosome doubling treatment. The protocol generated is low cost as it amalgamates field with controlled conditions. The vernalization treatment through domestic refrigerator makes the system applicable to institutes not have complete controlled facility. The only requirement of growth chamber is for 15 days duration between transition from refrigerator to field. Even this can be avoided or surpassed by choosing off season location to conduct the crosses. The three growing seasons provide flexibility in choosing the time as well as provides opportunity for corrective crosses.

In present, age when faster generation cycling protocols are coming up with six or more generation a year (Watson *et al* 2018), the concurrent use of tauschii under such situation was addressed by our study and it was established that three seed to seed cycles of *Ae. tauschii* can be grown in a calendar year.

REFERENCES

Alonso, L.C. and Kimber, G. (1984). Use of restitution nuclei to introduce alien genetic variation into hexaploid wheat. *Z Pflanzenzuecht* 92: 185-89.

Beales, J., Turner, A., Griffiths, S., Snape, J.W. and Laurie, D.A. (2007). A Pseudo-Response Regulator is misexpressed in the photoperiod insensitive Ppd-D1a mutant of wheat (Triticum aestivum L.). *Theor Appl Genet*., 115:721–733.

Cox, T.S., Harrell, L.G., Cken, P. and Gill, B. S. (1991). Reproductive behaviour of hexaploid/diploid wheat hybrids. *Plant Breed.*,107: 105-18.

Diaz, A., Zikhali, M., Turner, A.S., Isaac, P. and Laurie, D.A. (2012). Copy number variation affecting the Photoperiod-B1 and Vernalization-A1 genes is associated with altered flowering time in wheat (Triticum aestivum). *PLoS ONE* 7:e33234

Eig, A. (1929). Monographish-Kritische ubersicht der Gattung *Aegilops*. *Repertorium Specierum Novarum Regni Vegetabilis*. *Beihefte*, 55:1-28.

Fu, D., Szucs, P., Yan, L., Helguera, M., Skinner, J.S., Zitzewitz., J., Hayes, P.M. and Dubcovsky, J. (2005). Large deletions within the first intron in VRN-1 are associated with spring growth habit in barley and wheat. *Mol Genet Genomics* 273:54–65.

Gatford, K.T., Hearnden, P., Ogbonnaya, F., Eastwood, R.F. and Halloran, G.M. (2002). Novel resistance to pre-harvest sprouting in Australian wheat from the wild relative *Triticum tauschii*. *Euphytica*, 126: 67–76.

Gill, B. S. and Raupp, W. J. (1987). Direct genetic transfer from *Aegilops squarrosa* L. to hexaploid *Wheat. Crop Sci* 27: 445-50.

Gororo, N.N., Eagles, H.A., Eastwood, R. F., Nicolas, M. E. and Flood, R. G. (2002). Use of *Triticum tauschii* to improve yield of wheat in low lying environments. *Euphytica*, 123: 241-54.

Imtiaz, M., Ogbonnaya, F.C., Oman, J. and Van Ginkel, M. (2008). Characterization of QTLs controlling genetic variation for pre-harvest sprouting in synthetic backcross derived wheat lines. *Genetics*, 178: 1725–36.

Kimber, G. (1984). Technique selection for the introduction of alien variation in wheat. *Z Pflanzenzuecht*. 92: 15-21.

Kippes, N., Debernardi, J., Vasquez-Gross, H.A., Akpinar, B.A., Budak, H., Kato, K., Chao, S., Akhunov, E. and Dubcovsky, J. (2015). Identification of the VERNALIZATION 4 gene reveals the origin of spring growth habit in ancient wheats from South Asia. *Proc Natl Acad Sci*., 112:5401–5410.

Kippes, N., Zhu, J., Chen, A., Vanzetti, L., Lukaszewski, A., Nishida, H., Kato, K., Dvorak, J. and Dubcovsky, J. (2014). Fine mapping and epistatic interactions of the vernalization gene VRN-D4 in hexaploid wheat. *Mol Genet Genom*., 289:47–62.

Li, Y., Zhou, R., Wang, J., Liao, X., Branlard, G. and Jia, J. (2012). Novel and favorable allele clusters for end use quality revealed by introgression lines derived from synthetic wheat. *Mol Breeding.*, 29:627–643.

Mandeep, S., Bains, N. S., Kuldeep, S., Sharma, S. C. and Parveen, C. (2010). Molecular marker analysis of Karnal bunt resistant wheat- *Aegilops tauschii* introgression lines. *Plant Dis Res.*, 25:107–112.

Matsuoka, Y. and Nasuda, S. (2004). Durum wheat as a candidate for the unknown female progenitor of bread wheat: an empirical study with a highly fertile F_1 hybrid with *Aegilops tauschii* Coss. *Theor Appl Genet.*, 109: 1710-17.

Mc Fadden, E.S. and Sears, E.R. (1946). The origin of *Triticum spelts* and its free-threshing hexaploid relatives. *J Hered*., 37**:** 81-88.

Miranda, L.M., Murphy, J.P., Marshall, D. and Leath, S. (2006). *Pm34*: a new powdery mildew resistance gene transferred from *Aegilops tauschii* Coss. to common wheat (*Triticum aestivum* L.). *Theor Appl Genet.*, 113:1497–504.

Nestor, Kippes., Andrew, Chen., Xiaoqin, Zhang., Adam, J., Lukaszewski, J. and Dubcovsky. (2016). Development and characterization of a spring hexaploid wheat line with no functional VRN2 genes. *Theor Appl Genet*., 129:1417–1428.

Ogbonnaya, F.C., Abdalla, O.M., Mujeeb-Kazi., Kazi, A. G., Xu, S.S., Gosman, N., Lagudah, E.S., Bonnett, D., Sorrells, M. E., Tsujimoto, H. and Janick, J. (2013). Synthetic hexaploids: harnessing species of the primary gene pool for wheat improvement. *Plant Breeding Reveiws.* 37: 35–122.

Olson, E.L., Rouse, M.N., Pumphrey, M.O., Bowden, R.L, Gill, B.S. and Poland, J.A. (2013). Introgression of stem rust resistance genes Sr TA187 and Sr TA 171from *Aegilops tauschii* to wheat. *Theor Appl Genet.*, 126: 2477-84.

Pestova, E., Ganal, M.W. and Röder, M.S. (2000). Isolation and mapping of microsatellite markers specific for the D genome of bread wheat. *Genome*, 43:689–697.

Rasheed, A., Ogbonnaya, F.C., Lagudah, E., Appels, R. and He, Z. (2018). The goat grass genome's role in wheat improvement. *Nature Plants*, 4: 56-58.

Wang, J.R., Luo, M.C. and Chen, Z.X. (2013). *Aegilops tauschii* single nucleotide polymorphisms shed light on the origins of wheat D-genome genetic diversity and pinpoint the geographic origin of hexaploid wheat. *New Phytol*., 198: 925–937.

Watanabe, N., Fujii, Y., Takesada, N. and Martinek, P. (2006). Cytological and microsatellite mapping of genes for brittle rachis in a *Triticum aestivum-Aegilops tauschii* introgression line. *Euphytica*, 151:63–69

Watson, A., Ghosh, S., Matthew, J., William, S., Simmonds, J., Rey, M. D., Asyraf, M., Hatta, M., Hinchliffe, A., Steed, A., Reynolds, D., Nikolai, M., Breakspear, A., Korolev, A., Rayner, T., Laura., Riaz, A., William, M., Ryan, M., Edwards, D., Batley, J., Raman, H., Carter, J., Rogers, C., Domoney, C., Moore, G., Harwood, W., Nicholson, P., Mark, J., Ian, H., DeLacy., Zhou J., Uauy, C., Scott, A.B., Robert F.P., Brande, B., Wulff, H. and Hickey, T.L. (2018). Speed breeding is a powerful tool to accelerate crop research and breeding. *Nature Plants*, 41: 23-29.

Wilhelm, E.P., Turner, A.S. and Laurie, D.A. (2009). Photoperiod insensitive Ppd-A1a mutations in tetraploid wheat (Triticum durum Desf.). *Theor Appl Genet*., 118:285–294.

Yan, L., Loukoianov, A., Tranquilli, G., Helguera, M., Fahima, T. and Dubcovsky, J. (2003). Positional cloning of wheat vernalization gene VRN1. *Proc Natl Acad Sci*., 100:6263–6268.

RESEARCH ARTICLE

EFFECT OF BEST PLANT BIO-REGULATORS AND MICRONUTRIENT FOR GETTING HIGHER FRUIT SETTING IN MANGO (*MANGIFERA INDICA* L.) CV. AMRAPALI

Rajeev Kumar, V.K. Tripathi, Saurabh Tomar*, Mahendra Chaudhary and Ram Jeevan

Department of Horticulture, Chandra Shekhar Azad University of Agriculture and Technology Kanpur 208002 (U.P.) India
Email: chaudhary.csa@gmail.com

Received-02.12.2018, Revised-20.12.2018

Abstract: An investigation was carried out on 19 years old plantation of mango (*Mangifera indica* L.) cv. Amrapali at C.S.A.U.A.&T., Kanpur (U.P.) India, during the year 2013-2014. In all, 15 treatments foliar application of plant bio-regulators and micronutrient were tested in RBD design replicated thrice. The result concluded that pre-harvest application of GA_3 (40 ppm) + $ZnSO_4$ (1.0%) results in significant decrease in fruit drops, increase in fruit retention. The application of NAA (40 ppm) + $ZnSO_4$ (0.5%) results in significantly increase the number of fruits set per plant and minimum fruit set under control.

Keywords: Mango, GA_3, NAA, Zinc sulphate, Fruit drop

INTRODUCTION

The mango (*Mangifera indica* L.) is occupies a pre-eminent place amongst the fruit crops grown in India due to its wide adaptability, high nutritive value, richness in variety, delicious taste, pleasant flavor, attractive colour. Mango is belongs to family Anacardiaceae and one of the most important and delicious fruit of the tropical countries and hold a premier position amongst the commercial fruits, grown in India. It is also known as king of fruits and national fruit of India. Mango industry has vast potentiality to play vital role in the development of economic status of the country and better linkage in the international trade. It is indigenous to north-east India and north Myanmar in the foot-hills of the Himalaya and is said to have originated in the Indo-Burma region.

The major mango producing countries are including India, Bangladesh, Burma, Sri Lanka, China, Malaysia, Florida, Hawaii, Mexico, Thailand, Australia, Pakistan, Indonesia, Philippines. In India, its cultivation is mentioned since pre- historic times for more than 4000 year ago. India has a rich wealth of mango germplasm with more than 1000 varieties grown throughout the country. However, only about 21 of them are commercially cultivated in different regions (Yadav, 1997). The most well- known commercially cultivated varieties in northern region of India are Bombay Green, Langra, Dashehari, Lucknow Safeda and Chausa. Almost all northern cultivars are biennial in bearing habit. Consequently, a large number of promising hybrids have been evolved by desirable combinations to obtain regular bearing varieties. Among the promising mango hybrids, Amrapali is a well-known late maturing regular bearing dwarf hybrid. Fruit possesses excellent quality with high pulp per cent and TSS with deep orange red flesh colour and excellent taste. Well suited hybrid cultivar for commercial cultivation in northern region of the country. It was evolved at IARI, New Delhi as a result of cross between Dashehari (alternate bearer) and Neelum (regular bearer) in 1978. 'Amrapali' is superior in comparison to parents in fruit quality like high percentage of pulp, TSS, acidity and β- carotene content.

The foliar application of plant bio-regulators and micronutrients have immense important role in improving fruit set, productivity and quality of fruits. It has also beneficial role in the recovery of nutritional and physiological disorder in fruit trees. Foliar application is based on the principle that the nutrients are quickly absorbed by leaves and transported to different parts of the plant to fulfil the functional requirement of nutrition. Foliar application of nutrient is obviously an ideal way to evading the problem of nutrient availability. This method is highly helpful for the correction of trace element deficiencies, to restore disrupted nutrient supply and to overcome stress factors limiting their availability. This method has been commercialized in a number of fruit crops like Citrus, Pineapple and Guava *etc.*

Plant bio-regulators and micronutrient such as GA_3, NAA and $ZnSO_4$ play an important role for fruit set, fruit yield and quality. Zinc plays an important role in growth and development of fruits, vegetables and cereals. It is one of the essential elements for the formation of chlorophyll and hence useful towards photosynthetic activity. Zinc is a constituent of some enzymes, indole acetic acid in plants and essential for CO_2 evolution, utilization of carbohydrate, phosphorus metabolism and synthesis of proteins. Napthalene acetic acid is helpful in the induction of flowering, prevent shedding of buds, flowers and unripe fruits, enlarge fruit size and also increase the yield and quality of many fruits, whereas, GA_3

*Corresponding Author

application is found more effective in retaining the maximum fruit percentage per panicle with increase in fruit size and fruit weight in mango and in many other fruits.

Deficiency of auxins, gibberellins and cytokinins as well as high level of inhibitors appears to be the cause of fruit drop in mango trees (Krisanapook *et al*., 2000). Plant growth regulators have primitive role in minimizing the fruit drop at different stages. Plant growth regulators have potential to enhance productivity of fruits by bringing out a change in nutritional and hormonal status of the plant (Tripathi *et al*., 2006). Naphthalene acetic acid and CPPU are control fruit drop-reducing PGR. Many investigators found that, spraying mango trees with NAA at different concentrations increased fruit set percentages and fruit retention CPPU, like their natural analogs, it is known for promoting cell division and is therefore used for the increasing of fruit growth. CPPU increased fruit retention in different mango cultivars and growing regions (Burondkar *et al*., 2009 and Notodimedjo, 2000). Considering the problem of fruit drop and fruit setting, the investigation was carried out to study the effect of different PGRs viz., NAA (40 ppm) and CPPU (10 and 20 ppm) on fruiting, yield and quality characters of mango cv. Keshar. Napthalein acetic acid (NAA) @ 80 ppm spray at 30 days before flowering was found to improve flowering in mango (Davenport, 2007).

MATERIALS AND METHODS

The present investigation was carried out in the Department of Horticulture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) during 2013-2014. The 45 Mango trees having uniform growth were selected randomly for the study. The cultural operations and basal application of manures and fertilizers were applied as per recommended schedule for Mango plantation. In all 15 treatments viz., T_1-GA_3 (20 ppm), T_2-GA_3 (40 ppm), T_3-NAA (20 ppm), T_4-NAA (40 ppm), T_5-$ZnSO_4$ (0.5%), T_6-$ZnSO_4$ (1.0%), T_7-GA_3 (20 ppm) + $ZnSO_4$ (0.5%), T_8-GA_3 (20 ppm) + $ZnSO_4$ (1.0%), T_9-GA_3 (40 ppm) + $ZnSO_4$ (0.5%), T_{10}-GA_3 (40 ppm) + $ZnSO_4$ (1.0%), T_{11}-NAA (20 ppm) + $ZnSO_4$ (0.5%), T_{12}-NAA (20 ppm) + $ZnSO_4$ (1.0%), T_{13}-NAA (40 ppm) + $ZnSO_4$ (0.5%), T_{14}-NAA (40 ppm) + $ZnSO_4$ (1.0%), T_{15}-Control (water spray) were tested in randomized block design with 3 replications. spraying of plant bio regulators and micro-nutrient was done at pea stage of fruit set. Thereafter observations were recorded Number of fruits set per plant, Fruit drop (%), Fruit retention (%) and Number of fruits per plant.

RESULT AND DISCUSSION

The number of fruits set per plant was counted at pea stage and average number of fruits per plant was expressed presented in Table 1. The data pertaining to the number of fruits set per plant clearly indicate that plants treated with GA_3, NAA and zinc sulphate significantly increased the number of fruits set per plant as compared to untreated ones. The pre-harvest application of plant bio-regulators and micronutrient produced significantly higher number of fruits set per plant with the pre-harvest application of NAA (40 ppm) + $ZnSO_4$ (0.5%) and this number of fruits set per plant was significantly higher as compared to remaining all other treatments whereas, the minimum number of fruits set per plant was recorded under control. Among both plant bio-regulators, maximum number of fruits set per plant was recorded in GA_3 (20 ppm) treated plants closely followed by NAA (40 ppm) whereas, minimum number of fruits set per plant was recorded in NAA (20 ppm) treated plants. The number fruits drops per plant are presented in Table 2. Data pertaining to the drop per cent of fruits, it is clearly indicated that significantly minimum fruit drop per cent was obtained with the pre-harvest application of GA_3 (40 ppm) + $ZnSO_4$ (1.0%) and fruit drop per cent was significantly lowest as compared to remaining all other treatments under investigation. Among both plant bio-regulators, minimum fruit drop per cent was recorded in GA_3 40 ppm treated plants closely followed by NAA (20 ppm), whereas, maximum fruit drop per cent was recorded in GA_3 (20 ppm) treated plants. Data pertaining of retention of fruit per cent presented in Table 3. The significantly maximum fruit retention per cent was obtained with the pre-harvest application of GA_3 (40 ppm) + $ZnSO_4$ (1.0%) which is significantly higher than remaining all other treatments, except T_9 and T_2, which produced 13.90% and 13.73%, respectively, whereas, the minimum fruit retention per cent was recorded under control. The maximum fruit retention per cent was recorded in GA_3 (40 ppm) treated plants, which is statistically at par with NAA (20 ppm); whereas, the minimum fruit retention per cent was recorded in GA_3 (20 ppm) treated plants. The number of fruits per plant at harvesting time presented in Table 4. The significantly maximum fruits per plant was obtained with the pre-harvest application of NAA (40 ppm) + $ZnSO_4$ (0.5%) followed by 226 fruits with NAA (40 ppm) + $ZnSO_4$ (1.0%) treated plants and this number of fruits per plant was significantly higher than remaining all other treatments, whereas, the minimum fruits per plant was recorded under control. It is also observed that among both plant bio-regulators, the maximum fruits per plant was recorded in plants treated with NAA (40 ppm) followed by GA_3 (20 ppm), whereas, minimum fruits

per plant was recorded in NAA (20 ppm) treated plants. These results are in accordance with Ruby and Rani (2001) in litchi, Tripathi and Shukla (2010) in strawberry and Kumar *et al*. (2008) and Vashistha *et al.* (2010) in mango cv. Amrapali. Bhowmick and Banik (2011) also recorded maximum fruit retention percentage (7.25%) as well as maximum number of fruits at harvest (790.17/plant) with GA_3 at 40ppm. The present finding is also in conformity with Tripathi and Shukla (2008), Singh and Tripathi (2010) in strawberry. Ruby and Rani (2004), also noted higher yield with GA_3 (100 ppm) higher yield as well as greatest length, diameter, volume and weight of fruit with GA_3 (200 ppm) in mango cv. Amrapali.

Table 1. Effect of pre-harvest application of plant bio-regulators and micronutrient on number of fruits set per plant.

Treatments	Number of fruits set/plant
T_1 : GA_3 (20 ppm)	2025
T_2 : GA_3 (40 ppm)	2021
T_3 : NAA (20 ppm)	1988
T_4 : NAA(40 ppm)	2022
T_5 : $ZnSO_4$ (0.5%)	1979
T_6 : $ZnSO_4$ (1.0%)	1977
T_7 : GA_3 (20 ppm) + $ZnSO_4$ (0.5%)	2023
T_8 : GA_3 (20 ppm) + $ZnSO_4$ (1.0%)	2020
T_9 : GA_3 (40 ppm) + $ZnSO_4$ (0.5%)	2013
T_{10} : GA_3 (40 ppm) + $ZnSO_4$ (1.0%)	2009
T_{11} : NAA (20 ppm) + $ZnSO_4$ (0.5%)	2019
T_{12} : NAA (20 ppm) + $ZnSO_4$ (1.0%)	2016
T_{13} : NAA (40 ppm) + $ZnSO_4$ (0.5%)	2035
T_{14} : NAA (40 ppm) + $ZnSO_4$ (1.0%)	2026
T_{15} :Control (water spray)	1877
S. E. m ±	9.795
CD at 5%	28.383

Table 2. Influence of pre-harvest application of plant bio-regulators and micronutrient on fruit drop (%).

Treatments	Fruit drop (%)
T_1 : GA_3 (20 ppm)	90.69
T_2 : GA_3 (40 ppm)	86.27
T_3 : NAA (20 ppm)	87.84
T_4 : NAA(40 ppm)	89.11
T_5 : $ZnSO_4$ (0.5%)	92.47
T_6 : $ZnSO_4$ (1.0%)	91.83
T_7 : GA_3 (20 ppm) + $ZnSO_4$ (0.5%)	89.15
T_8 : GA_3 (20 ppm) + $ZnSO_4$ (1.0%)	87.20
T_9 : GA_3 (40 ppm) + $ZnSO_4$ (0.5%)	86.10
T_{10} : GA_3 (40 ppm) + $ZnSO_4$ (1.0%)	85.15
T_{11} : NAA (20 ppm) + $ZnSO_4$ (0.5%)	91.19
T_{12} : NAA (20 ppm) + $ZnSO_4$ (1.0%)	90.95
T_{13} : NAA (40 ppm) + $ZnSO_4$ (0.5%)	92.32
T_{14} : NAA (40 ppm) + $ZnSO_4$ (1.0%)	92.95
T_{15} :Control (water spray)	94.85
S. E. m ±	0.933
CD at 5%	2.716

Table 3. Influence of pre-harvest application of plant bio-regulators and micronutrient on fruit retention per cent.

Treatments	Fruit retention (%)
T_1 : GA_3 (20 ppm)	9.31
T_2 : GA_3 (40 ppm)	13.73
T_3 : NAA (20 ppm)	12.16
T_4 : NAA(40 ppm)	10.89
T_5 : $ZnSO_4$ (0.5%)	7.53

T_6 : $ZnSO_4$ (1.0%)	8.17
T_7 : GA_3 (20 ppm) + $ZnSO_4$ (0.5%)	10.85
T_8 : GA_3 (20 ppm) + $ZnSO_4$ (1.0%)	12.80
T_9 : GA_3 (40 ppm) + $ZnSO_4$ (0.5%)	13.90
T_{10} : GA_3 (40 ppm) + $ZnSO_4$ (1.0%)	14.85
T_{11} : NAA (20 ppm) + $ZnSO_4$ (0.5%)	8.81
T_{12} : NAA (20 ppm) + $ZnSO_4$ (1.0%)	9.05
T_{13} : NAA (40 ppm) + $ZnSO_4$ (0.5%)	7.68
T_{14} : NAA (40 ppm) + $ZnSO_4$ (1.0%)	7.05
T_{15} :Control (water spray)	5.15
S. E. m ±	0.450
CD at 5%	1.310

Table 4. Influence of pre-harvest application of plant bio-regulators and micronutrient on number of fruits per plant at harvest.

Treatments	**Number of fruits/plant at harvest**
T_1 : GA_3 (20 ppm)	215
T_2 : GA_3 (40 ppm)	211
T_3 : NAA (20 ppm)	188
T_4 : NAA(40 ppm)	222
T_5 : $ZnSO_4$ (0.5%)	179
T_6 : $ZnSO_4$ (1.0%)	178
T_7 : GA_3 (20 ppm) + $ZnSO_4$ (0.5%)	223
T_8 : GA_3 (20 ppm) + $ZnSO_4$ (1.0%)	224
T_9 : GA_3 (40 ppm) + $ZnSO_4$ (0.5%)	213
T_{10} : GA_3 (40 ppm) + $ZnSO_4$ (1.0%)	207
T_{11} : NAA (20 ppm) + $ZnSO_4$ (0.5%)	218
T_{12} : NAA (20 ppm) + $ZnSO_4$ (1.0%)	216
T_{13} : NAA (40 ppm) + $ZnSO_4$ (0.5%)	228
T_{14} : NAA (40 ppm) + $ZnSO_4$ (1.0%)	226
T_{15} :Control (water spray)	176
S. E. m ±	2.348
CD at 5%	6.185

REFERENCES

Bhowmick, N. and Banik, B. C. (2011). Influence of pre-harvest foliar application of growth regulators and micronutrients on mango cv. Himsagar. *Indian Journal of* Horticulture **68** (1): 103-107.

Burondkar, M.M., Jadhav, B.B. and Chetti, M.B. (2009). Post-flowering morpho-physiological behavior of Alphonso mango as influenced by plant growth regulators, polyamine and nutrients under rainfed conditions. *Acta Hort*.; 820 : 425-432.

Davenport (2007). Reproductive physiology of mango. Braz. J. Plant Physiol. **19** (4): 363-376.

Krisanapook, K., Phavaphutanon, L., Kaewladdakorn, P. and Pickakum, A. (2000). Studies on fruit growth, levels of GA – Like Substances and CK- Like substances in fruits of mango cv. Khiew Sawoey. *Acta Horticulturae*, 509 : 694-704.

Kumar, R., Kumar, P. and Singh, U. P. (2008). Effect of foliar application of nitrogen, zinc and boron on flowering and fruitingof mango (*Mangifera*

*indica*L.) cv. Amrapali. *Environment and Ecology*, **26** (4B): 1965-1967.

Notodimedjo, S. (1999). Effect of GA3, NAA and CPPU on fruit retention, yield and quality of mango (cv. Arumanis) in East Java. *Acta Horticulturae*, 509: 247-255.

Singh, V.K. and Tripathi, V.K. (2010). Efficacy of GA_3, boric acid and zinc sulphate on growth, flowering, yield and quality of strawberry cv. Chandler. *Progressive Agriculture*, **10** (2): 345-348.

Tripathi, V.K. and Shukla, P.K. (2006). Effect of plant bioregulator on growth, yield and quality of strawberry cv. Chandar. *J. Asian Hort*., **2** (4): 260.

Tripathi, V.K. and Shukla, P.K. (2010). Influence of plant bio-regulators, boric acid and zinc sulphateon yield and fruit characters of strawberry cv. Chandler. *Prog. Hort.* **42** (2): 186-188.

Vashistha, K., Yadav, A.L., Singh, H.K. and Yadav, D.K. (2010). Effect of foliar spray of nutrients on fruit drop, yield and quality attributes of mango fruit (*Mangifera indica*L.) cv. Amrapali. *Plant Archives*, **10** (1): 359-360.

Yadav, I. S. (1997). Mango research in India in the past 50 years. *Indian Horticulture*, **42** (2): 10-17.

RESEARCH ARTICLE

KNOWLEDGE AND ADOPTION OF RECOMMENDED MAIZE PRODUCTION TECHNOLOGY

P.K. Netam*, H.K. Awasthi and R.S. Sengar

1,2,3,Department of Agricultural Extension CoA, IGKV, Raipur, Chhattisgarh
Email: pknetam49@gmail.com

Received-06.12.2018, Revised-25.12.2018

Abstracts: This investigation was carried out in three district of Bastar plateau of Chhattisgarh State to assess the level of knowledge and adoption of recommended maize production technology. 270 farmers were considered as respondents for this study. Respondents were interviewed through personal interview. Collected data were analyzed with the help of suitable statistical methods. The analysis of the results showed that overall knowledge of recommended maize production technology, 72.96% respondents had medium level of knowledge and 73.70% respondents had medium level of adoption regarding recommended maize production technology.

Keywords: Maize production, Knowledge, Adoption, Technology

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in the world and has the highest production among all the cereals. It is a miracle crop, it has very high yield potential, there is no cereal on the earth which has so immense potentiality and that is why it is called 'queen of cereal'. Besides, maize has many types like normal yellow, white grain, sweet corn, baby corn, pop corn, waxy corn, high amylase corn, high oil corn, quality protein maize, etc. Maize is the most important crop in the world after wheat and rice (Verheys, Undated). It is an important staple food in many countries and is also used as animal feed and many industrial applications. Maize is 3rd major crop in India after rice and wheat (Cox, R., 1956 & Reddy *et. al.* 2013). Maize is important cereal crop which provides food, feed, fodder and serves as a source of basic raw material for a number of industrial products viz, starch, protein, oil, food sweeteners, alcoholic beverages, cosmetics, bio-fuel etc, it is cultivated over 8.12 million hectare area with an annual production of 19.77 million tones and an average productivity of 2,435 kg ha-1 (Langade *et. al*. 2013). Maize is the third most important food grain in India after wheat and rice. In India, about 28% of maize produced is used for food purpose, 11% as livestock feed, 48% as poultry feed, 12% in wet milling industry (for example starch and oil production) and 1% as seed (AICRP on Maize, 2007). Maize crop in the state has an area of 123430 ha with the production 254134 MT (C.G. Agriculture Statistic Report 2014).The area and production of Maize crop in Kanker district was 11511 ha and 25705 MT respectively, area of maize crop in Kondagaon district is 13586 ha with production of 31831 MT while the coverage of maize in Bastar district is 9560 ha with the production of 22398 (C.G. Ag. statistic Report 2014). Rogers(1983) Knowledge is of three types namely awareness knowledge, how to knowledge and principle knowledge In the present study operational knowledge was studied and study is confined as the technical information possessed by the respondents about recommended maize production technology. A device was developed to measure the knowledge level of respondents regarding to recommend maize production technique by adopting the scale suggested by Paikra (2014). Rogers (1995) described the adoption is mental process through which an individual passes from hearing about an innovation to final adoption. Adoption refers to the extent of use of recommended cultivation technique of maize by the respondents. The present study was undertaken with specific objectives to assess the level of knowledge and extent of adoption about recommended maize production technology among the respondents of Bastar plateau of Chhattisgarh.

MATERIAL AND METHODS

The present study was carried out in Bastar plateau of Chhattisgarh State. Three districts in the zone *i.e.* Kanker, Kondagaon and Bastar were undertaken for the study. Two blocks from each of the selected district Block Antagarh and Koylibeda in Kanker District, Keshkal and Baderajpur in Kondagaon, Bastar and Bakawand in Bastar District. Each selected block 3 villages *viz.* Irrabodi, Amagaon, Godri, in Antagarh Block, Chotekapsi, Kodosalhebhat, Manegaon, in Koylibeda Block, Cherbeda, Toraibeda, Amoda in Keshkal Block, Baderajpur, Toraipara, Khargaon(Manduki) in Baderajpur Block, Ikchapur, Bagmohlai, Dubeumargaon in Bastar Block, Belputi, Khotlapal and Mangnar in Bakawand Block were selected and from each selected village, 15 farmers were selected randomly. In this way total two hundred seventy respondents were selected to response as per the interview schedule designed for the study. Collected data were analyzed by the help of various statistical

*Corresponding Author

tools *i.e.* frequency, percentage, mean, standard deviation, correlation and regression, *etc.*

The knowledge test was composed of items called question for constructing the knowledge tests of all the recommended practices of maize production technology. A set of questions was developed and discussed with the subject matter specialist in the disciplines with subject matter specialist in the disciplines of advisory committee and then finalized. Total no. of question was 13. A device was developed to measure the knowledge level of respondents regarding to recommend maize production technique by adopting the scale categorised as follow.

Categories	Score
Incomplete knowledge	0
Partial knowledge	1
Complete knowledge	2

A knowledge index was worked out to assess the level of knowledge of each respondent with the help of following equation.

$$KI = \frac{O^i}{S} \times 100$$

Where,

K.I. = Knowledge index of I^{st} respondent

O^i = Total score obtained by the I^{st} respondent

S = Total obtainable score

Considering the knowledge score of the respondents were categorized in to following groups on the basis of knowledge index.

Category	Score
Low	Up to 33.33%
Medium	33.34-66.66%
High	Above 66.66%

To measure the extent of adoption, the list of recommended practices was prepared and responses for the each practice were obtained into three- point continuum as under.

Categories	Score
Not adopted	0
Partial adopted	1
Fully adopted	2

Adoption index was worked out for each respondent by using the following formula:

$$A.I = \frac{O^i}{S} \times 100$$

Where,

AI = Adoption index of i^{st} respondent

O^i = Total score obtained by the i^{st} respondent

S = Total obtainable score

Considering the adoption score of the respondents were categorized in to following groups on the basis of adoption index.

Category	Score
Low	Up to 33.33%
Medium	33.34-66.66%
High	Above 66.66%

RESULT AND DISSCUSION

The result and discussion of the present study have been summarized under the following heads:

Level of knowledge

The extent of overall knowledge of the respondent's data showed in Table No.1. It indicated 72.96% respondents had to medium level of knowledge,

followed 15.93% respondents were high level of knowledge and 11.11% respondents had to low level of knowledge about the maize production. The data indicates among the respondents regarding to recommend practices of maize production was observed medium level of knowledge respectively. Similar findings were supported by Yadav (2014) who reported 68.83% respondents had belong to medium level of knowledge about the improved tomato production technology in the study area.

Table 1. Extent of Knowledge of the respondents regarding recommended practices of maize cultivation (n=270)

S.N.	Category	Frequency	Percentage
1	Low (Up to 33.33%)	30	11.11
2	Medium (33.34-66.66%)	197	72.96
3	High (Above 66.66%)	43	15.93

The extent of knowledge had been tested with suitable parameters and represented in Table No. 2. The knowledge about the improved technology of maize cultivation from the different respondents had been analyzed and interpreted. It was observed that majority of the respondents of about 54.44% had partial knowledge about the selection of suitable land for maize cultivation and only 35.19% of the respondents had clear knowledge about the suitable land selection for the maize crop. The extent of knowledge about the selection of improved varieties and seed rate was comparatively higher as 45.93 and 51.50% respectively while, 43.70% and 44.40% of the respondents had partial knowledge about the improved varieties and seed rate, respectively. Poor knowledge of seed treatment was exhibited from the respondents. Only 0.74% of the respondents had complete knowledge of seed treatment and rest had shown the incomplete or partial knowledge.

Table 2. Distribution of the respondents by their extent of knowledge regarding to recommended practices of maize cultivation (n=270)

S.N.	Practice	Extent of Knowledge					
		Compl.		Partial		Incom.	
		F	Percentage	F	Percentage	F	Percentage
1	**Selection of suitable land**	95	35.19	147	54.44	28	10.37
2	**Improved varieties**	124	45.93	118	43.70	28	10.37
3	**Seed Rate**	139	51.50	120	44.40	11	4.10
4	**Seed Treatment**	2	0.74	5	1.85	263	97.41
5	**Sowing Time**	205	75.93	36	13.33	29	10.74
6	**Thinning**	9	3.33	51	18.89	210	77.78
7	**Fertilizer Application**						
	Chemical Fertilizer	45	16.67	218	80.74	7	2.59
	Organic Manure	11	4.10	220	81.50	39	14.40
8	**Micronutrient**	13	4.80	112	41.50	145	53.70
9	**Weed Control**						
	Manual	209	77.40	47	17.40	14	5.20
	Chemical	94	34.81	45	16.67	131	48.52
10	**Irrigation**	56	20.74	158	58.52	56	20.74
11	**Plant Protection**	19	7.04	145	53.70	106	39.26
12	**Harvesting**						
	Cob form	112	41.48	2	0.74	156	57.78
	Grain	261	96.67	7	2.52	2	0.74
13	**Threshing**						
	Maize Sheller	0	0.00	2	0.74	268	99.26
	Maize Thresher	261	96.67	7	2.52	2	0.74

The knowledge about the right time of sowing was expressed by the respondents. It was observed that majority of 75.93% of respondents had complete knowledge of appropriate time of sowing. Majority of the respondents lack of knowledge about the thinning and exhibited as 77.78% as incomplete knowledge.

Poor knowledge of nutrient management in maize crop was exhibited by the respondents. Majority of the respondents had partial knowledge of chemical fertilizer and organic manure to be applied in maize crop as 80.74 and 81.50% respectively. Similarly the knowledge about the micronutrient application in

maize crop exhibited incomplete knowledge of 53.70%.

Partial knowledge of irrigation in maize crop as 58.52% was expressed by the respondents. Poor knowledge of plant protection measures for maize crop was observed. It was found that 53.70% of the respondents had partial knowledge of suitable plant protection measures for maize crop whereas, 39.26% of the respondents had incomplete knowledge. The data was revealed by respondents for the weed management practices in maize crop, the 77.40% of the respondents were well aware about the manual weeding, majority of the respondents lack the knowledge about herbicide application under chemical weed control.

The extent of knowledge about the harvesting of maize crop showed the results majority of the respondents lack the appropriate harvesting of cob form maize, whereas they exhibited the sufficient knowledge about the harvesting of grain from maize crop, similarly appropriate knowledge about the adoption of maize thresher was exhibited by the respondents, about 96.67% of the respondents showed the complete knowledge about the maize threshing. Poor knowledge of maize Sheller was exhibited among the various respondents majority of the respondents of about 99.26% showed the incomplete knowledge.

Extent of adoption

Respondents are categorised in different groups on the basis of their extent of adoption for represented in Table No. 3. It is evident from the data that majority of the respondents had medium of level of adoption which was found 73.70% while 22.60% respondents had low extent of adoption. In contrary to this only 3.70% respondents had high extent of adoption for recommended practices of maize cultivation. Similar finding were reported by yadav (2014) in the study area who reported 74.17% respondents their adoption level had to medium respectively.

Table 3. Extent of Adoption of the respondents regarding recommended practices of maize cultivation (n=270)

S.N.	Category	Frequency	Percentage
1	Low (Up to 33.33%)	61	22.60
2	Medium (33.34-66.66%)	199	73.70
3	High (Above 66.66%)	10	3.70

Various recommended practices of maize cultivation are categorised and scaled on the base of their extent of adoption. Level of different recommended practices of maize cultivation are presented in Table No.4. It was observed that 35.56% of the respondents had partial adoption of technology namely selection of suitable land and only 31.48% of the respondents had complete adoption of the technology. 32.96% of respondents had no adoption for choosing suitable land for maize cultivation. The extent of adoption for selection of improved and 15.56% had complete adoption of chemical fertilizer, whereas 71.85% respondents had partial and 4.07% had adoption of organic manure. Application of varieties and seed rate was comparing high as 45.93% and 51.48% respectively, while 41.85 and 42.22% of the respondents had partial adoption for selection of improved varieties and proper seed rate, respectively. A very poor adoption of seed treatment was exhibited among all the respondents and 98.89% of the respondents had no adoption of seed treatment.

Table 4. Distribution of the respondents by their extent of adoption regarding to recommended practices of maize cultivation (n=270)

S.N	Practice	Extent of Adoption					
		Complete		Partial		Nil	
		F	%	F	%	F	%
1	**Selection of suitable land**	85	31.48	96	35.56	89	32.96
2	**Improved varieties**	124	45.93	113	41.85	33	12.22
3	**Seed Rate**	139	51.48	114	42.22	17	6.30
4	**Seed Treatment**	2	0.74	1	0.37	267	98.89
5	**Sowing Time**	149	55.19	55	20.37	66	24.44
6	**Thinning**	6	2.22	34	12.59	230	85.19
7	**Fertilizer Application**						
	Chemical Fertilizer	42	15.56	196	72.59	32	11.85
	Organic Manure	11	4.07	194	71.85	65	24.07
8	**Micronutrient**	12	4.44	42	15.56	216	80.00
9	**Weed Control**						
	Manual	183	67.78	73	27.04	14	5.19
	Chemical	9	3.33	36	13.33	225	83.33
10	**Irrigation**	55	20.37	117	43.33	98	36.30

11	**Plant Protection**	19	7.04	122	45.19	129	47.78
12	**Harvesting**						
	Cob form	6	2.22	27	10.00	237	87.78
	Grain	261	96.67	7	2.59	2	0.74
13	**Threshing**						
	Maize Sheller					270	100.00
	Maize Thresher	261	96.67	7	2.59	2	0.74

Complete adoption of right time of sowing among different respondents was found 55.19% and rest of the respondents had partial or no adoption for the technology. 85.19% of the respondents had no adoption for thinning practice in maize crop. Majority of the respondents as 72.59 and 71.85% had partial adoption for use of chemical fertilizer and organic manure, respectively while no adoption for use of micronutrient in maize crop was found 80% among different respondents.

Partial and no adoption of improved irrigation practices exhibited among the respondents as 43.33%, respectively. Poor adoption of plant protection measures was exhibited and found 47.78 and 45.19% as no adoption and partial adoption for the technology. In case of weed management contradictory results was observed. Complete adoption of manual weed management practices was exhibited among respondents as 67.78%, whereas, no adoption of chemical weeding existed as 83.33%.

The extent of adoption for harvesting and threshing exhibited the result. Majority of the respondents (96.67%) had lack the complete adoption of harvesting of maize as grain and use of thresher. Contrary to this 100% respondents had no adoption for maize Sheller while, 87.78% of respondents adopted harvesting of maize in cob form.

CONCLUSION

From the above research findings it can be concluded that majority of the respondents had medium level of knowledge and extent of adoption regarding recommended maize production technology.

REFERENCES

Bawa, D.B. and Ani, A.O. (2014). Analysis of Adoption of Improved Maize Production Technology among Farmers in Southern Borno, Nigeria. Research on Humanities and Social Sciences, 4(25): 137-141.

Chhattisgarh (2014). Annual statistics report.

CIMMYT (2005). Maize in India: production systems, constraints, and research priorities.

Gecho, Yishak and Punjabi, N.K. (2011). Determination of adoption of improved Maize technology in Damot Gale, Wolaita, Ethiopia. Raj. J. Ext. Edu., 19: 1-9.

Gupta, Km. Saroj and Gyanpur, S.R.N. (2012). Sustainability of scientific maize cultivation practice in Uttar Pradesh, India. Journal of Agricultural Technology. 8 (3): 1089-1098.

Langade, D. M., Shahi, J.P., Agrawal, V. K. and Sharma, A. (2013). Maize as emerging source of oil in india: an overview. Maydica, 58(3/4): 224-230.

Paikra, V. K. (2014). Assessment of technological gap in production of black gram among the tribal farmers of Jashpur District Chhattisgarh. M. Sc. (Ag.) Thesis, IGKV, Raipur.

R. Cox, (1956). Control of helminthosporium turcicum blight disease of sweet corn in South Florida. Phytopathology, 5: 68-70.

Reddy, T. R., Reddy, P. N., Reddy, R. R. and Reddy, S. S. (2013). Management of Turcicum leaf blight of maize, caused by Exserohilum Turcicum in maize. International Journal of scientific and Research publications, 3(10): 1-4.

Willy, V. (Undated). Soil plant growth and production Vo. II National Science foundation Flanders and geography department, Belgium: University of Ghenl . (accessed on 02/01/2013).

Yadav, S., Prajapati, R. R. and Prajapati, M.R. (2014). Knowledge and adoption of tomato growers about improved tomato production technology. Guj. J. Ext. Edu., 25(2): 172-174.

RESEARCH ARTICLE

INFLUENCE OF INTEGRATED NUTRIENT MANAGEMENT PRACTICES ON GROWTH AND SEED YIELD OF INDIAN MUSTARD (*BRASSICA JUNCIA* L.) CULTIVARS

Mamta*, Raghvendra Bahadur Yadav and Puspendra Kumar[1]

Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture &Technology, Meerut-250 110, UP.
[1]Department of Agronomy, C.S.A. University of Agriculture & Technology, Kanpur
Email: mamtarajput525@gmail.com

Received-02.12.2018, Revised-23.12.2018

Abstract: A field investigation was carried out during *Rabi* seasons of 2013-14 and 2014-15 at Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) to find out the influence of integrated nutrient management practices on growth and yield of Indian mustard (*Brassica juncia* L.) cultivars. Experiment consist five cultivars of Indian cultivars (Pusa Mustard 22 , Pusa Mustard 26, Pusa Mustard 27, Pusa Vijay and Pusa Mahak) and four practices of integrated nutrient management practices (100% RDF, 75% RDF + 2 tonne Vermicompost, 75% RDF + 2 tonne Vermicompost + Bio-fertilizer and 75% RDF + 2 tonne Vermicompost + Bio-fertilizer). The growth and seed yield of mustard significantly influence by different treatments. The maximum dry weight, crop growth rate and seed yield recorded under the cultivar Pusa Vijay with application of 75% RDF+2t VC +Bio-fertilizer whereas maximum plant height were recorded under the cultivar Pusa mustard 27 with application of 75% RDF+2t VC +Bio-fertilizer in both the years years.

Keywords: Growth, Management, Mustard, Nutrient, Seed

INTRODUCTION

Indian mustard [*Brassica juncia* L.] is an important oil seed crop of the world. It plays a major role in cooking edible oil demand of the country. Population of India is increasing rapidly and consequently edible oil demand is also going up day-by-day. Hence, it has become necessary to enhance the present production by developing superior varieties of Indian mustard. The contribution of rapeseed-mustard to the total oilseed production in India is 26.0 percent.

India is the third largest producer of rapeseed-mustard occupying 5.79 million hectares area with 6.31 million tonnes production (Piri *et al.*, 2011), but the average yield of rapeseed-mustard in India is only 1089 kg/ha due to the lack of optimum use of nutrients and improper management.

The integrated nutrient management practices is very necessary which is not only sustains high crop production over the years (Verma et al. 2010) but also improves soil health and environment (Vijaya Sankar Babu et al. 2007).. Vermicompost improves the soil physico -chemical properties along with direct release of macro as well as micronutrient; ultimately the crop yields and finally crop yields increase. Integration of chemical fertilizers along with vermicompost and Bio-fertilizers could be helping to improve soil fertility and productivity. Non-symbiotic bacteria like Azotobactor are potential bio-fertilizers. These are capable of contributing N to a number of non-legumes by tapping aerial nitrogen. Furthermore, activity of bio-fertilizers may be influenced by supply of nutrients like N to the soil. Therefore a field investigation was carried out to find out influence of integrated nutrient management practices on growth and yield of Indian mustard (*Brassica juncia* L.).

MATERIALS AND METHODS

A field experiment was conducted at Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) which is situated in Indo-Gangetic plains of Western Uttar Pradesh. The farm is geographically located at 290 13′ 96″ N latitude, 770 68′ 43″ E longitudes with an elevation of 228 metres above the mean sea level during *Rabi* seasons of 2013-14 and 2014-15 respectively. There were 20 treatment combinations comprising five new cultivar of mustard with four integrated nutrient management-INM practices. These treatments were assigned in split plot design with 3 replications. The soil of experimental site was sandy loam in texture, low in available nitrogen and organic carbon, medium in available phosphorus and potassium and alkaline in reaction. The recommended doses of fertilizers @ 120: 40: 40: 20 kg ha^{-1} NPK and S were uniformly applied during both years of experiment. The source of fertilizers was urea, single super phosphate and muriate of potash. Phosphorus and potash were applied as basal, whereas half dose of nitrogen was applied as basal and the remaining half dose was applied in two split doses, first at 30 days after seed sowing and second at the time of flowering. Vermicompost was applied as per treatment and mix in the soil before sowing. The soil was inoculated with bio-fertilizers (*Azotobacter*) before sowing the crop as per treatment. The crop was sown in lines at row spacing of 45 cm apart on October 16 and 18 during 2013

*Corresponding Author

and 2014, respectively. The recommended seed rates of 5 kg/ha for Indian mustard were used. The other recommended agronomic practices were adopted to harvest the good yield.

RESULTS AND DISCUSSION

Growth parameters

Data on plant height, dry mater production and relative growth rate are presented in table 1, 2 and 3. A perusal of the table-1 depicting the observations on plant height reveals a significantly difference between the treatment in all the observation record at 30, 60, 90 DAS and harvest. The tallest plant height were counts in cultivar Pusa Mustard 27 compare other variety during both years of experiments, however cultivar Pusa Mahak recorded minimum plant height due to varietal characteristics, this may be attributed to better proliferation of roots and increased uptake of nutrient.

In the case of integrated nutrient management maximum plant height recorded with application of 75% RDF+2t VC +Bio-fertilizer during both the years of experiment compare other treatments.

Table 1. Effect of different mustard cultivars and integrated nutrient management on plant height (cm) of Indian mustard at various crop growth stages during 2013-14 and 2014-15

Treatments	Plant height (cm)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Varieties								
Pusa Mustard 22	43.85	43.59	118.21	117.49	163.97	162.97	190.67	189.50
Pusa Mustard 26	43.38	43.12	116.95	116.22	162.21	161.21	188.62	187.45
Pusa Mustard 27	46.69	46.42	125.86	125.14	174.58	173.58	**203.00**	**201.83**
Pusa Vijay	44.84	44.57	120.87	120.15	167.66	166.66	194.96	193.79
Pusa Mahak	41.39	41.12	111.57	110.85	154.76	153.76	179.96	178.79
SEm±	**0.74**	**0.79**	**1.98**	**2.12**	**2.75**	**2.95**	**3.20**	**3.43**
C D (P=0.05)	**2.40**	**2.57**	**6.47**	**6.93**	**8.97**	**9.61**	**10.44**	**11.18**
INM levels								
100% RDF	41.81	41.54	112.69	111.97	156.32	155.31	181.76	180.60
75% RDF+2t VC	43.45	43.18	117.14	116.41	162.48	161.48	188.93	187.76
75% RDF+2t VC +Bio-fertilizer	45.47	45.21	122.57	121.85	170.02	169.02	**197.70**	**196.53**
50% RDF+4t VC +Bio-fertilizer	45.40	45.12	122.34	121.64	169.73	168.73	197.37	196.20
SEm±	**0.72**	**0.71**	**1.92**	**1.90**	**2.67**	**2.64**	**3.10**	**3.06**
C D (P=0.05)	**2.06**	**2.04**	**5.56**	**5.52**	**7.71**	**7.68**	**8.97**	**8.90**

Data on dry mater production are presented in table 2, which is clearly indicated that plant dry weight (g/plant) significantly differ between the treatment in all the observation record at 30, 60, 90 DAS and at harvest. The maximum dry weight (g/plant) were recorded in the cultivar Pusa Vijay followed by Pusa Mustard 22 compare other cultivar during both the years of experiments. The cultivar Pusa Mahak recorded minimum value of dry weight during investigation period. Nutrient apply through 75% RDF+2t VC +Bio-fertilizer recorded maximum dry weight compare other practices of INM, whereas minimum dry weight were found in 100 % RDF during both the years.

Table 2. Effect of different mustard cultivars and integrated nutrient management on plant dry weight at 30, 60, 90 DAS and at harvest during 2013-14 and 2014-15

Treatments	Plant dry weight (g/plant)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Varieties								
Pusa Mustard 22	13.78	14.54	28.77	29.70	49.15	49.08	59.94	60.61
Pusa Mustard 26	13.23	13.97	27.62	28.52	47.18	47.15	57.54	58.21
Pusa Mustard 27	13.30	14.08	27.76	28.74	47.42	47.51	57.83	58.66
Pusa Vijay	14.38	15.24	30.00	31.12	51.25	51.44	**62.50**	**63.50**
Pusa Mahak	12.38	13.16	25.84	26.87	44.14	44.42	53.84	54.84
SEm±	**0.15**	**0.14**	**0.32**	**0.31**	**0.55**	**0.52**	**0.67**	**0.64**
C D (P=0.05)	**0.50**	**0.49**	**1.05**	**1.02**	**1.80**	**1.68**	**2.20**	**2.07**
Nitrogen levels								
100% RDF	13.01	13.78	27.16	28.12	46.40	46.50	56.60	57.39
75% RDF+2t VC	13.05	13.81	27.23	28.20	46.51	46.60	56.72	57.52
75% RDF+2t VC +Bio-fertilizer	13.96	14.77	29.13	30.16	49.76	49.86	**60.69**	**61.56**
50% RDF+4t VC +Bio-fertilizer	13.64	14.44	28.47	29.50	48.64	48.75	59.32	60.18
SEm±	**0.26**	**0.27**	**0.54**	**0.55**	**0.92**	**0.91**	**1.12**	**1.12**
C D (P=0.05)	**0.74**	**0.78**	**1.55**	**1.60**	**2.65**	**2.63**	**3.23**	**3.24**

Data on crop growth rate are presented in table 3 clearly indicated that crop growth rate (g/m2/day) significantly differs between the treatment in all the observation record at 30-60 DAS, 60-90 DAS, 90 DAS to harvest. The cultivar Pusa Vijay were recorded maximum crop growth rate (g/m2/day)

followed by Pusa Mustard 22 compare other cultivar during both the years of experiments. The cultivar Pusa Mahak recorded minimum value of dry weight during investigation period. IMN through 75% RDF+2t VC +Bio-fertilizer recorded maximum crop growth rate (g/m2/day) compare other practices of INM, whereas minimum crop growth rate (g/m2/day) were found in 100 % RDF during both the years.

The increase in growth parameters of mustard was due to increased in nutrient availability through organics, as it releases major and minor nutrients gradually during whole growing season. Efficiency of organic sources, in general, is manifested in the fact that organic matters release nutrients after mineralization which improves the physical and physic-chemical properties of soil. Similar result was found with Yadav *et al.*, (2013) and Thaneshwar (2017). Nanwal *et al.* (2000) found that the growth of Indian mustard cultivars were increased with increasing levels of nitrogen along with Azotobacter.

Table 3. Effect of different mustard cultivars and integrated nutrient management on CGR at different growth stages during 2013-14 and 2014-15

Treatments	**Crop growth rate (g/m^2/day)**					
	30-60 DAS		**60-90 DAS**		**90 DAS to harvest**	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Varieties						
Pusa Mustard 22	0.50	0.51	0.65	0.68	0.36	0.38
Pusa Mustard 26	0.48	0.49	0.62	0.65	0.35	0.37
Pusa Mustard 27	0.48	0.49	0.63	0.66	0.35	0.37
Pusa Vijay	0.52	0.53	0.68	0.71	**0.38**	**0.40**
Pusa Mahak	0.45	0.46	0.58	0.61	0.32	0.35
SEm±	**0.005**	**0.006**	**0.007**	**0.008**	**0.004**	**0.005**
C D (P=0.05)	**0.018**	**0.020**	**0.022**	**0.026**	**0.013**	**0.014**
INM levels						
100% RDF	0.47	0.48	0.61	0.63	0.33	0.36
75% RDF+2t VC	0.47	0.48	0.62	0.64	0.34	0.37
75% RDF+2t VC +Bio-fertilizer	0.51	0.52	0.66	0.69	**0.37**	**0.39**
50% RDF+4t VC +Bio-fertilizer	0.49	0.50	0.64	0.67	0.36	0.38
SEm±	**0.009**	**0.010**	**0.012**	**0.013**	**0.007**	**0.008**
C D (P=0.05)	**0.027**	**0.029**	**0.036**	**0.037**	**0.020**	**0.021**

Seed yield

Seed yield data are presented in table 4 clearly indicated that seed yield (kg/ha) significantly differs between the treatment in all the observation. Seed yield was maximized under the cultivar Pusa Vijay followed by Pusa Mustard during both the years on mean basis. The cultivar Pusa Mahak recorded minimum value of dry weight during investigation period. IMN through 75% RDF+2t VC +Bio-fertilizer recorded maximum crop growth rate (g/m2/day) compare other practices of INM, whereas minimum crop growth rate (g/m2/day) were found in 100 % RDF during both the years.

The increased seed yield might be due to varietal characters and balance supply of major and minor nutrient. Addition of Vermicompost and biofertilizer (Azotobactor), besides its nutritional role might be involved in improving the physio- chemical properties of soil specially the moisture retention aggregate formation, soil aeration and enhanced microbial activity. The result of present study is conforming to Parihar *et al.* (2014), Satyajeet and Nanwal (2007) and Pal *et al.* (2008). Huang *et al.* (2007) found that the incorporation of inorganic fertilizers and biofertilizers along with organic fertilizers in Brassica campestris gave higher yields.

Table 4. Effect of mustard cultivars and integrated nutrient management on seed yield (kg ha^{-1}) of mustard crop during 2013-14 and 2014-15

Treatments	**Seed yield (kg ha^{-1})**	
	2013-14	**2014-15**
Varieties		
Pusa Mustard 22	1664.17	1684.16
Pusa Mustard 26	1430.83	1450.83
Pusa Mustard 27	1491.67	1511.66
Pusa Vijay	**1940.83**	**1960.83**
Pusa Mahak	1367.50	1387.50
SEm±	**36.20**	**47.42**
C D (P=0.05)	**117.91**	**154.48**
INM levels		
100% RDF	1464.00	1484.00
75% RDF+2t VC	1498.67	1518.66

75% RDF+2t VC +Bio-fertilizer	**1688.66**	**1708.66**
50% RDF+4t VC +Bio-fertilizer	1664.66	1684.67
SEm±	**40.76**	**40.88**
C D (P=0.05)	**117.78**	**117.92**

CONCLUSION

Based on above study suggested that Indian mustard cultivar Pusa Vijay with application of 75% RDF+2t VC +Bio-fertilizer (Azotobacter) integrated nutrient management practice give higher seed yield.

REFERENCES

Huang, J., Zhen, W., Shirong, G. and Shijun, L. (2007). Effect of types and applying amount of solid fertilizers on growth, quality and yield of Brassica campestris. Chinese Journal of Eco Agriculture 15(1): 45-48.

Nanwal, R.K., Thakral, S.K. and Kumar, R. (2000). Response of Indian mustard (Brassica juncea) cultivars to nitrogen and Azotobacter under conserved moisture conditions. Annals of Biology 16(1): 85-86.

Pal, Y., Singh, R.P., Sachan, R.S. and Pandey, P.C. (2008). Effect of integrated nutrient management practices on yield, nutrient uptake and economics of mustard (Brassica juncea L.) grown in rice-mustard cropping system. Pantnagar Journal of Research 6(2): 199-204.

Parihar, S., Kameriya, P.R. and Choudhary, R. (2014). Response of mustard to varying levels of sulphur and fortified vermicompost loamy sand soil. *Annals of Agri. Bio. Research* **19**(3): 413-415.

Piri, I., Nike, M.M., Tavassoli, A. and Rastegaripour, F. (2011). Effect of irrigation intervals and sulphur fertilizer on growth analyses and yield of Brassica juncea. African Journal of Microbiology Research, 5: 3640–3646.

Satyajeet and Nanwal, R.K. (2007). Integrated nutrient management in pearlmillet-mustard cropping system. Indian Journal of Fertilizers 3(4): 59-62.

Thaneshwar, Singh, V., Jai, Prakash, Kumar, M., Kumar, S. and Singh, R.K. (2017). Effect of Integrated Nutrient Management on Growth and Yield of Mustard (Brassica juncea L.) in Irrigated Condition of Upper Gangetic Plain Zone of India. International Journal of Current Microbiology and Applied Sciences 6 (1): 922-932.

Verma, Gayatri, Mathur, A.K., Bhandari, S.C. and Kanthaliya, P.C. (2010). Long term effect of integrated nutrient management on properties of a typic Haplustept under maize- wheat cropping system. Journal of the Indian Society of Soil Science. 58(3) : 299-302.

Vijaya, Sankar, Babu, M., Mastan, Reddy, C., Subramanyam, A. and Balaguravaiah, D. (2007). Effect of integrated use of organic and inorganic fertilizers on soil properties and yield of sugarcane. Journal of the Indian Society of Soil Science. 55: 161-166.

Yadav, S.S., Jakhar, M.L. and Yadav, L.R. (2013). Response of taramira to varying levels of fym and vermicompost under rainfed conditions. J. of oilseed brassica. 4(1): 49-52.