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RESEARCH ARTICLE

DROUGHT RESISTANCE PARAMETERS AS SELECTION PARAMETERS TO IDENTIFY DROUGHT TOLERANT RICE GENOTYPES

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Abstract: Multidimensional effect of drought on rice cultivation in Asia is a recurring climatic event. about 4.62 and 6 million ha area of rice in India in year 2002 and 2009, respectively had been reduced alone due to drought. The development of high yielding drought tolerant rice varieties for diverse nature of drought prone upland ecology is still in its infancy and germplasm still needs to be improved in rainfed eastern India. Considering this, this study has been done to evaluate early maturing genotypes over the season for upland areas of sufficient and deficit moisture regimes. Twenty seven genotypes in advanced yield trial less than 100 days (AYTLT 100 days) were tested for drought tolerance and yield performance. Results showed that Genotype x environment interaction accounted for 32 per cent of the total sum of squares, with environment and genotype responsible for 25 per cent and 43 per cent. There was also significant variation in the delay in flowering among drought stressed genotypes in which flowering time was similar under irrigated condition. Similarly, significant genotypic differences in Drought susceptibility index (DSI) based on grain yield (t ha^{-1}) in each year was also observed. Yield reduction was above 50 per cent except Lalsar in all the environments, while, yield reduction varied from 83.33 per cent in Brown Gora up to 99.28 per cent in RR 366-5 under severe drought stress. In case of desirable stability factor, among the genotypes, only Lalsar followed by CR 143-2-2 showed desirable stability factor for grain yield (t ha^{-1}). Results also revealed that 66 out 78 estimates of correlations assumed significant in all the years and out of 66 estimates of significant correlations, forty two had positive sign and fourteen were negative, mostly estimates were common in nature and led to similar inferences in all the years. Furthermore, the biplot analysis for indices showed that drought resistance parameters and their interaction with drought tolerance parameters were highly significant (P<0.001) and accounted for 94.6 and 3.6 per cent of the treatment combination sum of squares, respectively.

Keywords: Drought, DSI, DTE, G X E interaction, rice, biplot analysis

Abbreviations: AYTLT 100 days- Advanced Yield Trial Less Than 100 days, RY_{WW} - Relative yield under well water, RY_{SS} -Relative yield under stress condition, GMP - Geometric Mean, STI- Stress Tolerance Index, TOL- Stress Tolerance, MP- Mean Productivity, GMP- Geometric Mean Productivity, YRR- Yield Reduction Ratio, TOL- Stress Tolerance, DTI- Drought Tolerance Index; DSI- Drought Susceptibility Index, DTE- Drought Tolerant Efficiency, GY- Grain Yield; DFF- Days To Fifty Per Cent Flowering, HI- Harvest Index

INTRODUCTION

Multidimensional effect of drought on rice cultivation in Asia is a recurring climatic event and climatically induced phenomenon. India accounts for the largest share (13.57 m ha) of the total drought prone rice area in Asia where yield losses due to drought are reported to cost an average of US $259 million annually (Bernier *et al*., 2008). Drought alone reduced the area of rice about 4.62 and 6 million ha in year 2002 and 2009, respectively. In the eastern Indian states of Jarkhand, Orissa, and Chhattisgarh alone, rice production losses during severe droughts (about 1 year in 5) average about 40 per cent of total production, with an estimated value of $650 million (Pandey *et al*., 2005). These losses affect the poorest farmers and their communities disproportionately. Drought risk reduces productivity, even in favorable years, because farmers avoid investing in inputs when they fear crop loss. Therefore, droughts have long-term destabilizing effects. Grain yield may be drastically reduced when water deficit coincides with vegetative stage or intermittent and screening for drought resistance at the vegetative stage in the dry season had long been used (Chang *et al*., 1974; De Datta *et al*., 1988 and Pantuwan *et al*., 2004). The development of high yielding drought tolerant rice varieties for diverse nature of drought prone upland ecology is still in its infancy and germplasm still needs to be improved in rainfed eastern India. In the view of above, at CRRI, Cuttack considerable work has been done to evaluate early maturing genotypes over the season for upland areas of sufficient and deficit moisture regimes.

MATERIALS AND METHODS

Experimental site, design and tested genotypes

Field experiments conducted under well-watered (E_1) and managed stress (E_2) conditions by direct-sown, non-puddled and non-flooded in leveled fields. Drought stress was artificial imposed during the vegetative stage as managed stress environment under aerobic condition and experiments under well water condition where no stress was imposed are referred to as non-stress trials and conducted under an anaerobic soil environment with pounded water. Twenty seven genotypes in advanced yield trial less than 100 days (AYTLT 100 days) were tested for

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drought tolerance and yield performance. Performance under vegetative stage drought stress twelve genotypes were selected and evaluated over three years during dry season to study the magnitude and consistency of yield response of diverse, rainfed upland rice genotypes and to identify genotypes that confer drought tolerance at CRRI, Cuttack. The experiments were established by dry seeding in late January and exposing 30 days old seedlings to drought stress for more than 30 days in Alpha Lattice Design with three replications.

Crop management

Rice varieties were directly sown at 2-3 cm soil depth in dry and pulverized soil by hand plough with the seed rate of 60 Kg ha^{-1} to maintain 3-4 seeds per hill. This method gave uniform seedling emergence for all the plots in 6-8 days. Each plot was 4.5 m long and 5.0 m wide, row to row distance was 15 cm and plant to plant distance was 10 cm each plot. Fertilizer was applied at the rate of 80, 40, and 40 kg ha^{-1} of N, P_2O_5, and K_2O, respectively. One third of nitrogen and entire dose of P_2O_5 and K_2O were given as basal dressing and remaining N was split into two doses applied at maximum tillering and flowering stages. Recommended package of practices was followed to raise good crop. Weeds were controlled by treating plot by pre-emergence herbicide (Petrilachlore) after three days of sowing followed by two hand weeding. Need based pest control measures were taken as and when required.

Observations and evaluation

Ten plants from each plot were randomly chosen for recording observations on their days to fifty per cent flowering (DFF) and harvest index (HI). Observations on grain yield (GY) were recorded on the plot basis. The plot yield was recorded in grams in each line and then data was converted in tons to hectare basis. The effect of drought was assessed as percentage reduction in mean performance of characteristics under managed drought stress condition relatively to the performance of the same trait under well water condition. The levels of stress were monitored through tensiometers. The trials were re-irrigated only when the tensiometers reading reached to 80 kPa at 20 cm depth. Genotypes were visually scored for drought reaction at 10-12 per cent soil moisture content at 30-cm soil depth and below 90 cm water table depth. Grain yield and yield attributes were recorded at maturity after recovering the crop on re-irrigation. The data were analyzed by appropriate statistical analysis (Gomez and Gomez, 1984) using CropStat 7.2 (2009) programme.

To assess the selection criteria for identifying drought tolerant genotypes and high yielding genotypes under both the water regimes, ten drought tolerance indices *viz*., drought susceptibility index (DSI) by Fischer and Maurer (1978) and drought tolerant efficiency (DTE): yield stability parameters which are based on reduction under stress by Fischer and Wood (1981); drought tolerance index (DTI): yield reduction in per cent by Fernandez (1992); stress tolerance (TOL): differences in yield under stress (Y_S) and well water conditions (Y_I) by Rosielle and Hamblin (1981); geometric mean productivity (GMP): relative performance by Fernandez (1992); mean productivity (MP): average of Y_s and Y_{WW} by Rosielle and Hamblin (1981); stress tolerance index (STI): identify genotypes producing high Y_S and Y_{WW} by Fernandez (1992); rate of productivity (RP): ratio of Y_S and Y_I; yield reduction ratio (YRR): 1-(Y_S/Y_I) by Golestani and Assad (1998) and relative yield (RY_S and RY_{WW}): yield under drought divided by that of the highest yielding genotypes in population by Ahmad *et al*. (2003) were used.

RESULTS

Analysis of variance

The nature of genotype by environment (G x E) interaction in rainfed upland rice genotypes was examined using data for 12 genotypes under irrigated and vegetative stage stress during 2007, 2008 and 2009. Varieties were significantly varied from each other, indicating presence of genetic variability in the experimental materials while, all the characters were influenced by environments and recorded significant genotype x environment interactions (G x E).

Genotype x environment interaction accounted for 32 per cent of the total sum of squares, with environment and genotype responsible for 25 per cent and 43 per cent. Significant differences environments (E) and genotype x environment interactions (G x E) for all the characters indicating the differential response of genotypes in different environmental conditions. This is in agreement with earlier reports (Wade *et al*., 1999 and Panwar *et al*., 2008).

Drought susceptibility index for days to 50 per cent flowering (days) and harvest index

In rice, drought stressed plants delay flowering relative to well-watered plants. Drought in the vegetative development stage can delay flowering up to 3 to 4 weeks in photoperiod-insensitive varieties. The delay in flowering is largest with drought early in the vegetative stage and is smaller when drought occurs later. In present study, results revealed significant variation in the delay in flowering among drought stressed genotypes in which flowering time was similar under irrigated condition. The delay was negatively associated with grain yield (r = -0.41** in E_1, r = -0.51** in E_2 & r = -0.44** in E_3) and harvest index (r = -0.38** in E_1, r = -0.45** in E_2 & r = -0.52** in E_3) and positively associated with yield reduction percentage (r = -0.50** in E_1, r = -0.58** in E_2 & r = -0.54** in E_3). There was a negative (r = -0.35** in E_1, r = -0.41** in E_2 & r = -0.40** in E_3) relationship between delay in flowering time and grain yield under drought stress. Genotypes that had a shorter delay produced higher grain yield.

The drought stress in all the years, generally delayed flowering time in all the tested genotypes (Table 1). The estimate of DSI for genotype ranged from 0.49 (CR 143-2-2) to 3.70 (RR 440-167-2-13) in E_1, 0.21 (CR 143-2-2) to 2.18 (IR 76569-259-1-1-3) E_2 and 0.38 (Thara) to 2.72 (RR 440-167-2-13) in E_3. Kalinga III showed high DSI values (>1) over the years while, Vandana recorded low DSI (<1) value almost the years. The genotypes *viz*., CR 143-2-2, Lalsar, CBT 3-06 and Brown Gora were consistent performer and recorded low DSI and little delay in flowering.

The genotypes with drought resistance can be identified by measuring delay in flowering indicated by several studies (Pantuwan *et al*., 2002, Jongdee *et al*., 2006, Zou *et al*., 2007 & Bernier *et al*., 2008). The varieties for drought prone rainfed upland, less than 100 days duration is desirable. However, if flowering is delayed by more than a few days, severe yield losses usually occur. So, upland genotypes cannot have luxury of larger delay in flowering due to short maturing nature. It has been reported that the greater the delay in flowering, the greater the yield and harvest index reduction due to drought (Bernier *et al*., 2008 & Pantuwan *et al*., 2002). Early maturing cultivars may be affected severely by early season drought, whereas late maturing cultivars may have sufficient time to recover from it (Maurya and O'Toole, 1986). Furthermore, selection for drought tolerance did not alter days to flowering and non-significant differences were observed under severe stress and as well as under well water condition reported by Kumar *et al*. (2008). The variation in DSI among and within twelve rice genotypes was measured when plants were exposed to vegetative stage severe stress condition. Variation in the delay in flowering among genotypes that have been exposed to the same drought conditions can be used as an index of drought tolerance (Pantuwan *et al*., 2002).

A short delay in flowering was associated with lower yield under early season drought conditions, in contrast to the case of terminal drought. In which a short delay was advantageous. In formal case, early flowering varieties flowered before full recovery and hence yield decreased, whereas late flowering varieties had more time to recover before flowering took place. The result indicated that genotypes with drought resistance can be identified by using DSI or delay in flowering. Genotypes with a longer delay in flowering time were consistently associated with a larger yield reduction under severe stress condition. The consistent estimates of DSI or flowering delay were obtained among almost all the genotypes during across the years. However, Pantuwan *et al*. (2002) observed large genotype by environment interactions for grain yield and delay flowering and reported inconsistent estimates of DSI and flowering delay under various types of drought.

Rice genotypes with drought tolerance traits are known to produce the highest seed yield under severe stress conditions (Kamoshita *et al*., 2008). Because of the long time from the time of stress to harvest, drought-resistance traits during vegetative stage drought may not be related to grain yield (Lafitte *et al*., 2002). Plant growth resumes after vegetative stage drought and this recovery growth then affects the development of sink size as well as source supply to meet the demand of the grain. Field studies (Lilley and Fukai, 1994 and Mitchell *et al*., 1998) and pot studies (Wade *et al*., 2000; Kamoshita *et al*., 2004) both show genotypic variation in short term recovery growth (e.g., 1 week to a few weeks) after vegetative stage drought, and these authors have reported the relationships between this genotypic variation and the amount of leaf remaining at the end of drought and the ability to tiller after drought.

Although the benefits of short term drought recovery traits on yield are difficult to demonstrate, a number of studies have shown that later maturing and longer growth duration cultivars show less growth stagnation and drought damage and have a higher yield when they encounter mild water shortages during the vegetative to panicle initiation stages (e.g., Fukai and Cooper, 1995; Hayashi *et al*., 2006 and Ikeda *et al*., 2008).

Drought resistance parameters

Drought susceptibility index (DSI) and drought tolerance efficiency (DTE)

Drought susceptibility index (DSI) is represents drought tolerance at whole plant level regardless of drought tolerance mechanism in operation (Chauhan *et al*., 2007). The selected genotypes for lower drought susceptibility index may have diverse tolerance mechanisms rather than based on single drought tolerant traits because drought tolerance is a complex phenomenon and does not always solely depend on single plant trait. Therefore, such type of genotypes may successfully cope with drought under range of environments.

The DSI for the various characteristics is presented in Table 3. There were significant genotypic differences in DSI based on grain yield (t ha^{-1}) in each year (Table 4). Drought susceptibility index which was one of the drought resistance parameters were ranged from 0.53 (Lalsar) to 0.91 (Kalinga III) in E_1; 0.53 (Lalsar) to 0.90 (CBT 3-06) in E_2 and 0.53 (Lalsar) to 0.96 (Thara) in E_3. The mean values of DSI for grain yield in all the years were below 1 (0.79 in E_1 & E_2, 0.80 in E_3), indicating the relative tolerance for grain yield in tested genotypes which recorded low DSI consistently over the years. Genotype with low DSI values (less than 1) can be considered to be drought resistant (Chauhan *et al*., 2007) because they exhibited smaller yield reductions under severe stress compared with well water conditions than the mean of all genotypes. Differences in DSI between genotypes were observed for all characteristics under investigation. A genotype with low DSI must have some characteristics that prevent the loss of yield under drought, but will not be desirable if those yields are below average.

Another drought tolerant parameter, DTE and values of this parameter were ranged from 18 (Kalinga III) to 52 (Lalsar) in E_1; 16 (CBT 3-06 & Thara) to 50 (Lalsar) in E_2 and 20 (Kalinga III & Thara) to 62 (Lalsar) in E_3. While, Lalsar had the highest DTE and lowest DSI values followed by CR 143-2-2 in all the years. Interestingly, above mentioned genotypes recorded high yields (>1 t ha^{-1}) under drought but showed low yield potential (<3 t ha^{-1}) under irrigated condition, might be because of high inherent tolerance to drought stress.

Drought tolerant genotypes in general have high DTE, low DSI and minimum reduction in grain yield under severe stress. The reduction in most of the characteristics under drought condition could be attributed to decreased translocation of assimilates and growth substances, impairing nitrogen metabolism, loss of turgidity and consequently reduced sink size. In view of this, Lalsar and CR 143-2-2 were identified as the most drought tolerant genotypes among the tested genotypes. On the other hand, Thara, Vandana and Kalinga III were the drought sensitive genotypes with maximum yield loss in comparison to above said genotypes.

The reduction in seed yield under stress condition among the different genotypes across the years, which ranged between 38 per cent and 84 per cent, while, earlier findings where large yield reductions in rice under drought stress conditions were reported (Ouk *et al*., 2006 and Pantuwan *et al*., 2002). Genotypes differed in DSI, but the estimate of the DSI was almost consistent across drought stress years. Pantuwan *et al* (2002) used this method to estimate the magnitude of the response of genotypes to a particular drought stress environment and reported inconsistent estimate of DSI among most of the experiments due to differences in timing and intensity of water stress. Although large variation persist between stress condition, genotypes with low DSI and high yield potential performed consistently across the stress conditions for most of the genotypes. Thus DSI was shown to be associated with drought tolerance. Ouk *et al*. (2006) reported that this techniques can be used to identify genotypes that confer drought tolerance. These findings differ from that of Pantuwan *et al*. (2002) who suggested that there was no consistency of DSI across varying drought environments. Considering the assimilate partitioning in component traits, Lalsar increased the grain yield. Further, it had the highest DTE, least DSI and highest percentage increase in the grain yield due to stress. So, the preliminary findings showed *Lalsar* was the most drought tolerant genotype among the tested ones. In present study, significant correlations were observed between GY_{WW} and GY_{SS}, and drought stress parameters (DTE and DSI). Similar findings were reported by Bahar and Yildirim (2010) and found positive correlation (r=0.416*) between GY_{SS} and DTE, and a negative correlation (r=-0.620**) between GY_{WW} and DTE. While, significant negative correlation was found between DTE and DSI. In addition to this, they suggested that these indices can be easily used to find drought tolerant genotypes in wheat breeding programme.

Drought tolerance index (DTI), Stress tolerance (TOL), mean productivity (MP), geometric mean (GMP), stress tolerance index (STI) and yield reduction ratio (YRR):

Drought tolerance index indicated the percentage reduction in grain yield caused by drought stress. In present study, yield reduction was above 50 per cent except Lalsar in all the environments and CR 143-2-2 in E_3 only, while, yield reduction varied from 83.33 per cent in Brown Gora up to 99.28 per cent in RR 366-5 under severe drought stress.

Genotypes with high TOL values are sensitive to stress and selection must be done based on low rates of this index in order to selecting drought tolerant genotypes. Lalsar, RR 440-167-2-13 and CR 143-2-2 genotypes in all the year, from this view had the yield stability among the other genotypes. Using MP and TOL indices, it can be separated genotypes producing high yields solely under well water condition. Furthermore, Kalinga in E_1 and E_2 and CBT 3-06 in E_3 had the highest MP value and hence, had the highest genotypic yield under irrigated condition. Based on GMP, genotypes, Kalinga, CBT 3-06 and CR 143-2-2 in E_1, E_2 and E_3, so could be classified as genotypes with high yields under both conditions. According to Fernandez (1993), more stable genotypes have higher rates of STI. Using this index, genotypes having remarkable yields under stress and non stress conditions could be recognized. Based on this index, Kalinga and CBT 3-06 were classified as moderate tolerant genotypes. In respect of YRR, low value is desirable and Lalsar and CR 143-2-2 recoded low value for this index in all the environments.

Relative yield under well water (RY_{WW}) and stress condition (RY_{SS}) and Rate of productivity

A stress tolerant genotype as defined by DSI need necessarily not have a high yield potential. The mean relative grain yields values under imposed water stress and well water conditions were 0.70 in E_1, 0.66 in E_2 and 0.59 in E_3 and 0.73 in E_1, 0.67 in E_2 and 0.72 in E_3, respectively. Mean relative yield in case of water stress was less than that of irrigated conditions. The genotypes CR 143-2-2 (0.93), Lalsar (0.85) and IR 76569-259-1-1-3 (0.70) in E_1; CR 143-2-2 (1.01), Kalinga III (0.78), RR 440-167-2 (0.78), Lalsar (0.74) and CB 0-13-1 (0.67) in E_2 and CBT 3-06 (0.96), Vandana (0.96), CR 143-2-2 (0.78) and Lalsar (0.65) in E_3 were relatively high yielding under severe stress condition (RY> mean RY), while rest of the genotypes in all the environments were relatively low yielding (RY< mean RY) in this treatment.

In the present study, among the genotypes, only Lalsar followed by CR 143-2-2 showed desirable stability factor for grain yield (t ha^{-1}). Contrary to this rest of the genotypes were showed unfavorable stability factor (SF<1) except two above said genotypes (Table 3). None of the genotypes recorded relatively greater value of stability factor ratio (>1.00) for grain yield (t ha^{-1}). Cursory view of stability factors for grain yield *vis-à-vis* that stability of grain yield in respect of promising hybrids was imparted by component traits. This superior performance of such genotypes for stability could possible is attributed to the pre dominance of non-fixable effects.

Correlation Coefficient

In the present study, 66 out 78 estimates of correlations assumed significant in all the years and out of 66 estimates of significant correlations, forty two had positive sign and fourteen were negative, mostly estimates were common in nature and led to similar inferences in all the years. It appears that the adverse nature of severe drought condition brought increase in degree of character associations (Table 5).

In this study, statistically significant correlations between grain yields under well water condition (GY_{WW}), grain yield under severe stress (GY_{SS}), and drought stress parameters (DTE and DSI) were obtained. Thus, negative correlation (r= -0.890** in E_1, -0.801** in E_2 and -0.604** in E_3, $p < 0.01$) was shown between GY_{WW} and DTE while positive correlation (r= 0.607** in E_1, 0.687** in E_2 and 0.664** in E_3, $p < 0.01$) between GY_{SS} and DTE. Also, there was a positive correlation (r= 0.891** in E_1, 0.803** in E_2 and 0.604** in E_3, $p < 0.01$) between GY_{WW} and DSI; and negative correlation (r= -0.605** in E_1, -0.683** in E_2 and -0.664** in E_3, $p < 0.01$) between GY_{SS} and DSI. In addition, a great negative correlation (r = - 0.999***) over the years, $P < 0.001$) was found between DTE and DSI.

To determine the most desirable drought tolerance criteria, the correlation coefficient between Y_{WW}, Y_{SS} and other quantitative indices of drought tolerance were calculated (Table 5). The correlation matrix, indicated strong and significant ($p< 0.01$) correlation of GY_{WW} with DSI, DTI and YRR simultaneously, above said indices showed strong negative association with GY_{SS}. Also, grain yield was positively and significantly correlated with DTE, TOL and RP under stress environment, while this relationship stronger in irrigated conditions. There were positive significant correlations among GY_{WW} and (MP, GMP and STI) and GY_{SS} and (MP, GMP and STI). The correlation coefficient for RY_{WW} *vs*. grain yield under well water condition (GY_{WW}) and RY_{SS} *vs*. grain yield under severe stress (GY_{SS}) were positive and strong in all the years. Non significant and negative associations were found between GY_{WW} and GY_{SS} over the years.

In the present study, a very strong negative association of DSI was observed with DTE, TOL, RP and RY_{SS}. On the other hand, DTI followed by YRR, RY_{WW} GMP and STI were found to be most important associates of DSI. The two indices *viz*., RY_{WW} and RY_{SS} were exhibited strong positive correlations with GMP and STI.

All the parameters studied above helped to select the lines, which may be promising for dry land conditions, but it is difficult to conclude that which parameters(s) is more effective than the other for screening the drought resistant genotypes. To solve this problem, correlation studies were made between the drought parameters in each variety and presented in Table 5.

Grain yield under well water condition was not correlated with severe stress condition suggesting that a high potential yield under optimum condition does not necessarily result in improved yield under stress condition like above, GY_{SS} *vs* RY_{WW} and GY_{WW} *vs* RY_{SS} were adversely correlated. Almost all the indices were highly correlated with each other as well as with GY_{SS} and GY_{WW}. Thus, through these indices it is possible to distinguish high yielding genotypes in either condition. GY_{WW} and GY_{SS} had significant and positive correlation with GMP and results of Ramirez *et al*. (1998) confirmed this matter. GY_{SS} with STI, GMP and STI had negative and significant correlation which is in agreement with Golabadi *et al*. (2006). Pleiotropy and/or linkage may also be the genetic reason for this type of negative association. Moreover, the correlations among STI, MP and GMP exhibited same trend, thus they can be introduced as the most desirable indices for screening drought tolerance genotypes. Nazari and Pakniyat (2010) stated the importance of stress intensity and reported that STI is most desirable index for drought tolerance.

The correlation coefficient of DSI with GY_{WW} was high and positive while, that of TOL with GY_{SS} was high and negative. Thus, selection for tolerance should decrease yield in the well water condition and increase grain yield under severe stress. The correlation coefficients of TOL with GY_{SS} and that of SSI with GY_{WW} were negligible by Saba *et al*. (2001). The greater the TOL value, the larger the yield reduction under severe stress condition and the higher the drought sensitivity. The lack of a correlation between TOL and GMP and between TOL and STI would indicate that the combination of high GMP and STI with low TOL can accessible in rice (Nazari and Pakniyat, 2010). Mean productivity was not correlated with RY_{SS} and yield under severe stress (Table 5). While, above said index negatively correlated with stability factor. Correlation coefficient values for MP index indicated that increase in yield potential would not beneficial for developing high yielding genotypes for water limiting or drought prone areas. GY_{SS} and GY_{WW} had significant and positive correlation with MP which was completely in accordance with Ferrandez (1993). In present study, TOL and DSI associated with all the indices except MP with TOL. However, TOL and SSI were not strongly correlated with the above mentioned indices reported by Saba *et al* (2001).

Fernandez (1993) compared effectiveness of several stress tolerance criteria (GMP, MP, DSI, STI, TOL) and concluded that MP, DSI and TOL failed to identify genotypes with both high yield and stress tolerance potentials, whereas through STI, genotypes with these attributes could be identified. Clark *et al* (1992) observed year-to-year variation in DSI within genotypes as well as changes in genotype ranking within years. Limitations of using the DSI and TOL indices have already been described in wheat (Clarke *et al*., 1992). Therefore, on the basis of the results and earlier studies, DSI, DTE, STI and TOL seem to be useful yield-based drought tolerance indices to be employed in plant breeding programs for rice.

The conventional method of partitioning total variation in to components, convey little information on the individual pattern of response (Zobel *et al*., 1988). To increase accuracy, additive main effects and multiplicative interaction is the first model of choice when main effects and interaction are both important. Many researchers has been used the biplot analysis for comparison of different genotypes for different criteria and in different crops. Kaya *et al*. (2002) were reported that wheat genotypes with larger IPCA 1 and lower IPCA 2 scores gave high yields (stable genotypes) and genotypes with lower IPCA 1 and larger IPCA 2 scores had low yields (unstable genotypes). In present study, drought tolerance indices which accounted for 94.6 per cent of the total sum square and the genotype by drought tolerance indices interaction effects which captured 3.6 per cent which accounted for principal component analysis (PCA) were significant indicating that two out of three sources are important in the analysis. The results showed that indices main effect was the most important source of variation, due to its large contribution to the total sum of squares. Variation due to drought tolerance indices was larger than that due to interaction, but interaction was significant meaning that differences among genotypes vary across indices. The IPCA1 explained 72.4 per cent of the interaction sum of square with yield potential and drought tolerance. Similarly, the second principal component axis named as stress tolerant dimension explained 26.6 per cent of interaction sum of square. Genotypes or indices with large negative or positive IPCA1 scores have high interactions, while those with IPCA1 scores near zero (close to the horizontal line) have little interaction across indices and *vice versa* for indices (Crossa *et al*., 1991) and are considered more stable than those further away from the line. Thus, selection of genotypes that have high PCA 1 and low PCA 2 are suitable for favorable and stress conditions. Therefore, genotypes Lalsar, RR 440-167-2-13 and CR 143-2-2 are desirable for both water regimes. Similarly, Nazari and Pankniyat (2010) reported 69.27 per cent for IPCA 1 with five drought tolerance indices.

Biplot analysis

The biplot analysis for indices showed that drought resistance parameters and their interaction with drought tolerance parameters were highly significant ($P<0.001$) and accounted for 94.6 and 3.6 per cent of the treatment combination sum of squares, respectively. Biplot analysis confirmed correlation analysis between studied criteria. As indicated by the F-test, the first two interaction PCA axes were highly significant. The IPCA1 and IPCA2 declared 72.4 and 26.6 per cent of the observed drought resistance parameters by genotypes variation sum of squares, respectively.

Table 1. Drought Susceptibility Index (DSI) for days to 50 per cent flowering (DFF) and harvest index (HI) in Upland rice genotypes

Genotypes	Drought Susceptibility Index (DSI)											
	Days to 50 per cent flowering (Days)				Plant Height (cm)				Harvest index			
	2007	2008	2009	Pooled	2007	2008	2009	Pooled	2007	2008	2009	Pooled
Brown Gora	0.68	1.01	0.54	0.74	1.07	1.03	1.15	1.09	1.06	1.10	1.94	1.37
CB 0-13-1	1.21	1.22	1.79	1.41	1.50	1.75	1.69	1.67	1.05	0.99	1.71	1.25
CBT 3-06	0.75	1.94	1.64	1.44	1.60	1.56	1.44	1.56	0.84	0.94	1.65	1.14
CR 143-2-2	0.49	0.21	0.90	0.53	0.85	1.16	-0.14	0.65	0.84	1.04	1.79	1.22
IR 76569-259-1-1-3	0.82	2.18	1.37	1.46	0.78	0.58	0.83	0.74	0.89	0.94	1.71	1.18
Kakro	0.76	1.79	1.21	1.25	1.72	1.44	1.74	1.66	1.04	0.99	1.76	1.26
Kalinga	1.13	2.02	1.80	1.65	0.72	0.84	0.84	0.80	1.03	1.02	1.77	1.27

Lalsar	0.70	0.89	0.91	0.83	0.58	0.70	-0.28	0.34	0.89	0.80	1.59	1.09
RR 383-2	1.20	0.83	1.17	1.07	0.93	1.00	0.99	0.98	1.06	1.07	1.89	1.34
RR 440-167-2-13	3.70	0.31	2.72	2.24	0.31	0.10	0.24	0.19	0.78	0.71	1.49	0.99
Thara	0.99	1.03	0.38	0.80	0.68	0.88	0.86	0.82	1.06	1.07	1.87	1.33
Vandana	0.79	0.93	1.09	0.94	0.93	0.68	1.62	1.10	0.96	0.88	1.65	1.16
Mean	1.10	1.19	1.29	1.19	0.97	0.97	0.91	0.97	0.96	0.96	1.73	1.22

Table 2. Analysis of variance for days to 50 per cent flowering, harvest index and their drought tolerance indices in upland rice genotypes

Source of Variation	Mean Sum of Squares							
	Days to 50 per cent flowering				Harvest index			
	DTF (I)	DTF (S)	DSI	DTE	HI (I)	HI (S)	DSI	DTE
Year	1476.12**	3796.59**	0.22	930.50**	0.02**	0.05**	7.24**	1409.76**
Genotype	367.09**	341.64**	2.18	361.66	0.02**	0.004	0.11**	278.29**
Year x Genotype	57.48	134.95	2.49	519.11	0.01	0.001	0.008	26.29

Table 3. Estimates of drought susceptibility index (DSI), drought tolerance efficiency (DTE), drought tolerance index (DTI) and rate of productivity (RP) of upland rice genotypes for grain yield (t ha^{-1})

Genotypes	Grain yield (t ha^{-1})															
	2007				2008				2009				Pooled			
	DSI	DTE	DTI	RP	DSI	DTE	DTI	RP	DSI	DTE	DTI	RP	DSI	DTE	DTI	RP
Brown Gora	0.83	23	77	0.23	0.82	24	76	0.24	0.94	22	78	0.22	0.86	23.08	77	0.23
CB 0-13-1	0.84	23	77	0.23	0.80	26	74	0.26	0.95	20.83	79	0.21	0.86	23.15	77	0.23
CBT 3-06	0.85	22	78	0.22	0.92	16	84	0.16	0.75	37.45	63	0.37	0.84	25.07	75	0.25
CR 143-2-2	0.80	26	62	0.38	0.83	23	60	0.40	0.33	72.29	50	0.50	0.68	39.38	61	0.39
IR 76569-259-1-1-3	0.77	30	70	0.30	0.89	18	82	0.18	0.90	25.34	75	0.25	0.86	23.83	76	0.24
Kakro	0.78	28	72	0.28	0.84	23	77	0.23	0.91	24.87	75	0.25	0.84	24.99	75	0.25
Kalinga	0.89	18	82	0.18	0.88	19	81	0.19	0.97	19.53	80	0.20	0.91	18.86	81	0.19
Lalsar	0.66	39	48	0.52	0.66	40	50	0.50	0.35	71.30	38	0.62	0.57	49.58	46	0.54
RR 383-2	0.82	25	75	0.25	0.85	22	78	0.22	0.93	22.61	77	0.23	0.87	22.93	77	0.23
RR 440-167-2-13	0.65	41	59	0.41	0.67	38	62	0.38	0.75	37.51	62	0.38	0.69	38.67	61	0.39
Thara	0.86	21	79	0.21	0.91	16	84	0.16	0.97	19.51	80	0.20	0.91	18.77	81	0.19
Vandana	0.87	20	80	0.20	0.90	17	83	0.17	0.67	44.37	56	0.44	0.83	26.51	73	0.27
Mean	0.80 ±0.02	28 ±1.23	72 ±1.26	0.28 ±0.02	0.83	26	74	0.26	0.79	34.79	68	0.32	0.81 ±0.008	27.91 ±0.71	72 ±0.71	0.28 ±0.007

Table 4. Analysis of variance for GY_{WW}, GY_{SS} and drought tolerance indices in upland rice genotypes

Source of Variation	Mean Sum of Squares											
	GY_{WW}	GY_{SS}	DSI	DTE	DTI	TOL	MP	GMP	STI	YRR	RP	RY (WW)	RY (SS)
Year	1.77**	0.36**	0.07**	337.55**	337.55**	0.36**	0.60**	0.44**	6.60**	0.03**	0.03**	0.04**	0.13**
Genotype	5.41**	0.23**	0.13**	1043.93**	1043.93**	0.23**	1.38**	0.53**	6.89**	0.10**	0.10**	0.25**	0.11**
Year x Genotype	0.22**	0.13**	0.02**	103.90**	103.90	0.13**	0.09**	0.13**	2.31**	0.01**	0.01**	0.01**	0.05**

GY_{WW}: Grain yield under well water condition GY_{SS}: Grain yield under severe stress condition

Table 5. Correlation matrix of drought tolerance indices, grain yield under stress and well water condition in upland rice

Correlation Coefficient	Env.	GY_S	GY_I	DSI	DTE	DTI	TOL	MP	GMP	STI	YRR	RP	RY_I	RY_S
GY_S	**E_1**	**1.00**	-0.261	-0.605**	0.607**	-0.607**	1.00**	0.211	0.445**	0.465**	-0.605**	0.605**	-0.262	0.999**

	E_2	**1.00**	-0.195	-0.683**	0.687**	-0.687**	1.00**	0.165	0.515**	0.536**	-0.688**	0.688**	-0.193	0.999**
	E_3	**1.00**	-0.136	-0.664**	0.664**	-0.664**	1.00**	0.201	0.831**	0.845**	-0.664**	0.664**	-0.199	0.999**
GY_1	**E_1**		**1.00**	0.891**	-0.890**	0.890**	-0.261	0.988**	0.867**	0.855**	0.891**	-0.891**	0.999**	-0.263
	E_2		**1.00**	0.803**	-0.801**	0.801**	-0.195	0.978**	0.735**	0.715**	0.799**	-0.799**	0.999**	-0.195
	E_3		**1.00**	0.604**	-0.604**	0.601**	-0.135	0.925**	0.659**	0.631**	0.603**	-0.603**	0.999**	0.138
DSI	**E_1**			**1.00**	-0.999**	0.999**	-0.605**	0.822**	0.605**	0.583**	0.999**	-.0999**	0.891**	-0.606**
	E_2			**1.00**	-0.999**	0.999**	-0.683**	0.674**	0.250**	0.314**	0.999**	-.0999**	0.803**	-0.682**
	E_3			**1.00**	-0.999**	0.999**	-0.683**	0.474**	0.520**	0.378**	0.999**	-.0999**	0.602**	-0.661**
DTE	**E_1**				**1.00**	-1.00**	0.607**	-0.821**	-0.303	-0.581**	-.0999**	0.999**	-0.889**	0.608**
	E_2				**1.00**	-1.00**	0.687**	-0.670**	-0.245	-0.209	-.0999**	0.999**	-0.800**	0.686**
	E_3				**1.00**	-1.00**	0.664**	-0.574**	-0.152	0.179	-.0999**	0.999**	-0.602**	0.661**
DTI	**E_1**					**1.00**	-0.607**	0.821**	0.303	0.581**	0.999**	-.0999**	0.889**	-0.608**
	E_2					**1.00**	-0.687**	0.670**	0.245	0.509**	0.999**	-.0999**	0.800**	-0.683**
	E_3					**1.00**	-0.664**	0.474**	0.152	0.479**	0.999**	-.0999**	0.602**	-0.661**
TOL	**E_1**						**1.00**	-0.111	0.545**	0.565**	-0.605**	0.605**	-0.263	0.999**
	E_2						**1.00**	0.015	0.515**	0.536**	-0.688**	0.688**	-0.193	0.999**
	E_3						**1.00**	0.501**	0.831**	0.845**	-0.663**	0.664**	-0.138	0.999**
MP	**E_1**							**1.00**	0.931**	0.921**	0.821**	-0.821**	0.988**	0.115
	E_2							**1.00**	0.859**	0.843**	0.669**	-0.669**	0.978**	0.014
	E_3							**1.00**	0.894**	0.875**	0.573**	-0.273	0.926**	0.303
GMP	**E_1**								**1.00**	0.996**	0.205	-0.205	0.866**	0.442**
	E_2								**1.00**	0.996**	0.243	-0.248	0.736**	0.515**
	E_3								**1.00**	0.996**	0.152	-0.152	0.662**	0.833**
STI	**E_1**									**1.00**	0.283	-0.583**	0.853**	0.461**
	E_2									**1.00**	0.208	-0.508**	0.716**	0.535**
	E_3									**1.00**	0.178	-0.478**	0.634**	0.847**
YRR	**E_1**										**1.00**	-1.00**	0.890**	-0.606**
	E_2										**1.00**	-1.00**	0.799**	-0.687**
	E_3										**1.00**	-1.00**	0.601**	-0.660**
RP	**E_1**											**1.00**	-	0.606**

													0.891**	
	E2											**1.00**	-0.799**	0.687**
	E3											**1.00**	-0.601**	0.660**
RY W	**E1**												**1.00**	-0.266
	E2												**1.00**	-0.194
	E3												**1.00**	-0.142
RY S	**E1**													**1.00**
	E2													**1.00**
	E3													**1.00**

Table 6. Principal component loading for the grain yield (t ha^{-1}) of upland rice genotypes

Component	**Proportion of total variation (%)**	**Variables**												
		GY (I)	**GY (S)**	**DSI**	**DTE**	**DTI**	**TOL**	**MP**	**GMP**	**STI**	**YRR**	**RP**	**RY (I)**	**RY (S)**
PC1	72.4	-0.26	0.09	0.01	4.89	-4.78	0.09	-0.09	-0.01	-0.11	0.01	0.10	-0.02	0.08
PC2	26.6	0.53	-0.08	-0.28	-0.24	-0.31	-0.08	0.23	0.10	0.88	-0.28	-0.28	-0.08	-0.11

CONCLUSION

Yield is a complex character which mainly depends upon several component characters. So, direct selection of yield alone is not much effective in development of drought tolerant genotypes. Selection based on a combination of indices may provide a useful criterion for improving drought tolerant of rice. Meanwhile, if two indices show negative correlation it would be difficult to exercise simultaneous selection for these indices in the development of a variety for drought prone areas of rice. Hence, under such situations, judicious selection programme might be formulated for simultaneous improvement of such important developmental and component characters.

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RESEARCH ARTICLE

PERFORMANCE OF GARLIC GENOTYPES FOR THRIPS AND PURPLE BLOTCH RESISTANCE

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Abstract: A field experiment was conducted to screen the different garlic genotypes against thrips infestation at Department of Vegetable Science, College of Horticulture, Kolar during *Rabi* season of 2016-17. Out of twenty six genotypes, Yamuna Safed, Ranebennur Local, Jamnagar Local, Mandsaur Local, GN-14-01, Ooty Local and Baram Local-06 were recorded thrips population less than 6.93 per plant and were categorized as resistant. While, genotypes *viz*., Bhima Purple, Yamuna Safed-2, Yamuna Safed-3, Yamuna Safed-4, Yamuna Safed-5, Yamuna Safed-8, Yamuna Safed-9, Baram Local-06, Jamnagar Local, Mandsaur Local, Ranebennur Local, Ooty Local, GRS-1330, GN-14-25, GN-14-15, DWG-2 and DWG-1 (check) were found to be resistant against purple blotch disease.

Keywords: Garlic, Genotypes, Thrips, Purple blotch

INTRODUCTION

Garlic (*Allium sativum* L.) is the second most widely cultivated vegetable cum spice crop after onion, under the genus *Allium* and belongs to the family Alliaceae having chromosome number 2n (2X) = 16. India is the second largest garlic producing country with the production of 12.52 lakh tonnes from 2.31 lakh hectares area with average productivity of 5.44 tonnes per hectare. In India major garlic producing states are Madhya Pradesh, Gujarat, Uttar Pradesh, Rajasthan, Assam, Punjab and Maharashtra. In Karnataka, garlic is grown during *Rabi* season in an area of 5.19 thousand hectares with the production of 5.47 thousand tonnes and a productivity of 1.05 tonnes per hectare (Anon, 2015). However, many factors affecting the production and productivity of garlic, of which infestation of insect pests and disease are the major one. Among different insect pests, Thrips (*Thrips tabaci*) is a serious and major biological constraint in garlic production causing heavy economical loss, if infestation starts at bulb initiation stage (Patel and Patel, 2012). Thrips prefers to feed on newly emerged leaves in the center of neck. Therefore, majority of thrips are found at the base of the youngest leaves in the lower center of the neck. Similarly, purple blotch (*Alternaria porri*) is a serious foliar disease causes major damage to the foliage up to 90 per cent in susceptible varieties. Screening of varieties with combined resistance to insect pest and diseases acts as preventive measure and are free from environmental pollution problems. From the above facts, the study was designed to screen out different resistant genotypes or cultivars of garlic against thrips and purple blotch.

MATERIAL AND METHODS

An experiment was conducted at Department of Vegetable Science, College of Horticulture, Kolar, Karnataka. In the experiment 26 garlic genotypes such as Bhima Purple, Bhima Omkar, Yamuna Safed, Yamuna Safed-2, Yamuna Safed-3, Yamuna Safed-4, Yamuna Safed-5, Yamuna Safed-8, Yamuna Safed-9, Baram Local-06, HG-17, Jamnagar Local, Mandsaur Local, Ranebennur Local, Maharashtra Sangam, Ooty Local, GRS-1328, GRS-1345, GRS-1330, GN-14-27, GN-14-01, GN-14-25, GN-14-15, GN-14-05, DWG-2 and DWG-1 (Check) were collected from different institutions and local cultivated areas across the country. The researchwas laid out in Randomized Complete Block Design (RCBD) with 2 replications. The sowing of cloves was done in beds of 2.0 m x 1.5 m (3m^2 area) size at a spacing of 15 cm x 10 cm in last week of September, 2016. The agronomic practices such as application of recommended dose of fertilizers, irrigation and weeding etc., were carried out as per the package of practices of UHS, Bagalkot. The thrips population was counted at seven days interval starting from the first appearance of infestation. The number of thrips (both nymphs and adults) was recorded from 20 randomly selected plants in each plot by keeping a white paper below the plant and then shaking the plants with finger. The tested genotypes were also grouped into four categories of resistance *viz.*, highly resistant, resistant, susceptible

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and highly susceptible based on number of thrips per plant. For the grouping purpose, mean value of individual genotype ($\overline{Xi}$) was compared with mean value of all genotypes ($\overline{X}$) and standard deviation (sd) following the modified scale adopted by Patel and Patel (2012). The retransformed data were used for computation of $\overline{X}$, $\overline{Xi}$ and sd in case of this parameter. The scale was used for categorizing different genotypes as below.

Category of resistance	Scale of resistance
Highly resistant (HR)	$\overline{Xi} < (\overline{X}$- sd)
Resistant (R)	$\overline{Xi} > (\overline{X}$- sd) $< \overline{X}$
Susceptible (S)	$\overline{Xi} > \overline{X} < (\overline{X}$+sd)
Highly susceptible (HS)	$\overline{Xi} > (\overline{X}$+sd) $< (\overline{X}$+2 sd)

Here, $\overline{X}$ = Mean value of all genotype, $\overline{Xi}$ =Mean value of individual genotype, sd =Standard deviation and n= No. of genotypes

$$\mathrm{Sd} = \sqrt{\mathrm{E}(\mathrm{X}-\overline{\mathrm{X}})^2/\mathrm{n}-1}$$

The disease assessment of purple blotch was done by tagging ten randomly selected plants and Per cent Disease Index (PDI) was recorded on a 0-5 class rating scale: **0** = Immune (No infestation), **1** = Resistant (R) (1-10 % Leaf Area Infected), **2** = Moderately Resistant (MR) (11-20 % LAI), **3** = Moderately Susceptible (MS) (21-40 % LAI), **4** = Susceptible (S) (41-60 % LAI), **5** = Highly Susceptible (HS) (61 % LAI and above).The PDI was calculated as given by Dhiman*et al.* (1986).

Per cent Disease Index (%) = $\dfrac{\text{Sum of all class ratings}}{n \times 5} \times 100$

Where, **n** = Number of leaves examined.
5 = Maximum class ratings in the scale.

RESULTS AND DISCUSSION

The performance of garlic genotypes with respect to vegetative growth, yield traits, thrips and purple blotch resistance is discussed in Table-1, 2 and 3. The results revealed that Yamuna Safed-9 was tallest with a plant height of 70.44 cm and it was at par with Mandsaur Local (69.29 cm) and Yamuna Safed-2 (69.27 cm) and Yamuna Safed-3 (69.04 cm). Whereas, the genotype GN-14-05 (47.21 cm) was found shortest. The results were similar to the findings of Islam *et al.* (2004); Moustafa *et al.* (2009).

The results revealed that none of the genotypes was highly resistant to thrips infestation. However, genotypes Yamuna Safed, Ranebennur Local, Jamnagar Local, Mandsaur Local, GN-14-01, Ooty Local and Baram Local-06 showed thrips population less than 6.93 but more than 5.74 per plant were grouped into resistant. While, genotypes Bhima Omkar, Yamuna Safed-2, Yamuna Safed-3, Yamuna Safed-5, Yamuna Safed-9, HG-17, Maharashtra Sangam, GRS-1328, GRS-1345, GRS-1330, GN-14-25, GN-14-15, GN-14-05 and DWG-2 were found susceptible by recording thrips population more than 6.93 but less than 8.12 per plant. Whereas, genotypes Yamuna Safed-8, DWG-1, Yamuna Safed-4, GN-14-27 and Bhima Purple recording thrips population more than 8.12, but less than 10.50 per plants were grouped into highly susceptible. The similar results were reported by Hossain *et al.* (2014) data revealed that cultivar GC-0034 noticed significantly lowest thrips population (6.97 thrips/plant). While, highest thrips population (15.18, 14.10 and 15.96 thrips/plant) were documented from the garlic genotype GC-0013, GC-0028 and GC-0030, respectively.

The results with respect to purple blotch indicated that, none of the genotypes found to be immune. However, genotypes *viz*., Bhima Purple (10.4 %), Yamuna Safed-2 (6.40 %), Yamuna Safed-3 (4.40 %), Yamuna Safed-4 (5.20 %), Yamuna Safed-5 (6.80 %), Yamuna Safed-8 (4.80 %), Yamuna Safed-9 (8.40 %), Baram Local-06 (4.00 %), Jamnagar Local (5.60 %), Mandsaur Local (7.60 %), Ranebennur Local (4.00 %), Ooty Local (6.80 %), GRS-1330 (10.00 %), GN14-25 (10.00 %), GN14-15 (9.20 %), DWG-2 (7.60 %) and check DWG-1 (6.00 %) were found to be resistant. Where as, five genotypes like Yamuna Safed (11.60 %), HG-17 (14.40 %), GRS-1345 (14.40 %), GN-14-27 (14.00 %) and GN14-01(12.40 %) were found to be moderately resistant. While, GRS-1328 (22.40 %) recorded to be moderately susceptible and GN14-05 (54.80 %) were found to be susceptible. However, one genotype Bhima Omkar (65.20 %) found to be highly susceptible. These findings were in accordance with findings of Pandey *et al.* (2000), Alam*et al.* (2007), Mishra *et al.* (2009) and Agarwal and Tiwari (2013).

The results revealed that the genotype Yamuna Safed-3 (14.51 t/ha) was recorded the highest yield and it was on par with Yamuna Safed-2 (12.94 t/ha) and these were significantly higher than Yamuna Safed-9 (12.10 t/ha) followed by Yamuna Safed-5 (12.05 t/ha), Yamuna Safed-4 (10.71 t/ha) and GRS-1330 (10.46 t/ha). However, the lowest yield was documented in check DWG-1 (4.25 t/ha). The susceptible genotypes produced higher yield compared to resistant cultivar which might be due to environmental conditions during growth phase and varietal characters.

Categorization of genotypes or cultivars

The different genotypes or cultivars of garlic were grouped into four different categories of resistance to thrips *viz*., highly resistant, resistant, susceptible and highly susceptible. The results are presented in Table 2. Among the genotypes evaluated, Yamuna Safed, Ranebennur Local, Jamnagar Local, Mandsaur Local, GN-14-01, Ooty Local and Baram Local-06 were found resistant to thrips infestation. While, genotypes Bhima Omkar, Yamuna Safed-2, Yamuna Safed-3, Yamuna Safed-5, Yamuna Safed-9, HG-17, Maharashtra Sangam, GRS-1328, GRS-1345, GRS-1330, GN-14-25, GN-14-15, GN-14-05 and DWG-2 were found susceptible. Whereas, genotypes Yamuna Safed-8, DWG-1, Yamuna Safed-4, GN-14-27 and Bhima Purple were grouped into highly susceptible.

The different genotypes or cultivars of garlic were grouped into five different categories of resistance to purple blotch such as immune, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible. The results are presented in Table 3.The results indicated that, none of the genotypes were found to be immune. However, genotypes *viz*., Bhima Purple, Yamuna Safed-2, Yamuna Safed-3, Yamuna Safed-4, Yamuna Safed-5, Yamuna Safed-8, Yamuna Safed-9, Baram Local-06, Jamnagar Local, Mandsaur Local, Ranebennur Local, Ooty Local, GRS-1330, GN-14-25, GN-14-15, DWG-2 and check DWG-1 found to be resistant. Whereas, five genotypes like Yamuna Safed, HG-17, GRS-1345, GN-14-27 and GN-14-01were found to be moderately resistant. While, GRS-1328 revealed to be moderately susceptible and GN-14-05 was found to be susceptible. However, one genotype Bhima Omkar was found to be highly susceptible.

Table 1. Performance of garlic genotypes for growth, yield traits, thrips and PDI (%)

Sl. No.	Genotypes	Plant height (cm)	Bulb yield (t/ha)	Thrips per plant	PDI (%)
1	**Bhima Purple**	54.13	7.06	9.30	10.40
2	**BhimaOmkar**	56.27	5.45	7.20	65.20
3	**Yamuna Safed**	66.87	9.87	5.85	11.60
4	**Yamuna Safed-2**	69.27	12.94	7.40	6.40
5	**Yamuna Safed-3**	69.04	14.51	7.88	4.40
6	**Yamuna Safed-4**	67.45	10.71	9.55	5.20
7	**Yamuna Safed-5**	68.41	12.05	7.58	6.80
8	**Yamuna Safed-8**	67.82	8.73	8.45	4.80
9	**Yamuna Safed-9**	70.44	12.10	7.75	8.40
10	**Baram Local-06**	61.04	7.54	6.00	4.00
11	**HG-17**	64.86	8.69	7.08	14.40
12	**Jamnagar Local**	65.91	7.84	5.78	5.60
13	**Mandsaur Local**	69.29	9.18	5.95	7.60
14	**Ranebennur Local**	48.48	5.57	5.90	4.00
15	**Maharashtra Sangam**	68.54	8.15	7.75	9.60
16	**Ooty Local**	67.92	9.20	5.93	6.80
17	**GRS-1328**	49.80	6.00	7.13	22.40
18	**GRS-1345**	53.67	6.37	7.88	14.40
19	**GRS-1330**	65.36	10.46	6.95	10.00
20	**GN-14-27**	54.03	6.23	9.45	14.00
21	**GN-14-01**	55.64	7.71	5.85	12.40
22	**GN-14-25**	56.09	7.51	7.45	10.00
23	**GN-14-15**	55.64	5.27	7.75	9.20
24	**GN-14-05**	47.21	5.60	6.95	54.80
25	**DWG-2**	58.56	5.85	7.65	7.60
26	**DWG-1 (Check)**	53.80	4.25	8.80	6.00
	SEm±	**3.47**	**0.80**	**-**	**-**
	CD at 5%	**10.11**	**2.34**	**-**	**-**

Table 2. Categorization of different genotypes of garlic for their susceptibility to thrips (*Thrips tabaci* Lindman)

Sl. No.	Category of resistance	Scale	Genotypes/cultivars ($\bar{X}$i)	
	***Based on population of thrips/plant :** $\bar{X}$= 6.93 and sd = 1.19			
1	**Highly resistant (HR)**	$\bar{X}$i< 5.74	-	-
2	**Resistant (R)**	$\bar{X}$i>5.74<6.93	**Yamuna Safed**	5.85

			Ranebennur Local	5.90
			Jamnagar Local	5.78
			Mandsaur Local	5.95
			GN-14-01	5.85
			Ooty Local	5.93
			Baram Local-06	6.00
3	**Susceptible (S)**	X̅i>6.93<8.12	**BhimaOmkar**	7.20
			Yamuna Safed-2	7.40
			Yamuna Safed-3	7.88
			Yamuna Safed-5	7.58
			Yamuna Safed-9	7.75
			HG-17	7.08
			Maharashtra Sangam	7.75
			GRS-1328	7.13
			GRS-1345	7.88
			GRS-1330	6.95
			GN-14-25	7.45
			GN-14-15	7.75
			GN-14-05	6.95
			DWG-2	7.65
4	**Highly Susceptible (HS)**	X̅i>8.12<10.50	**Yamuna Safed-8**	8.45
			DWG-1	8.80
			Yamuna Safed-4	9.55
			GN-14-27	9.45
			Bhima Purple	9.30

***** n=20

Table 3. Incidence of purple blotch (*Alternaria porri* Ellis) of different genotypes of garlic

Sl. No.	**Category of resistance**	**Scale (PDI)**	**Purple blotch**	
			Genotypes	**PDI**
1	**Resistant (R)**	1-10 %	**DWG-1**	6.00
			DWG-2	7.60
			GN-14-15	9.20
			Yamuna Safed-2	6.40
			Yamuna Safed-3	4.40
			Yamuna Safed-4	5.20
			Yamuna Safed-5	6.80
			Yamuna Safed-8	4.80
			Yamuna Safed-9	8.40
			Baram Local-06	4.00
			Jamnagar Local	5.60
			Mandsaur Local	7.60
			Ranebennur Local	4.00
			Maharashtra Sangam	9.60
			Ooty Local	6.80
			GRS-1330	10.00
			Bhima Purple	10.40
			GN-14-25	10.00
2	**Moderately Resistant (MR)**	11-20%	**Yamuna Safed**	11.60
			GRS-1345	14.40
			HG-17	14.40
			GN-14-27	14.00
			GN-14-01	12.40
3	**Moderately Susceptible (MS)**	21-40%	**GRS-1328**	22.40

4	**Susceptible (S)**	41-60%	**GN-14-05**	54.80
5	**Highly Susceptible (HS)**	61% and above	**BhimaOmkar**	65.20

CONCLUSION

In the study, genotypes Yamuna Safed, Ranebennur Local, Jamnagar Local, Mandsaur Local, GN-14-01, Ooty Local and Baram Local-06 were found resistant to thrips infestation and genotypes Bhima Purple, Yamuna Safed-2, Yamuna Safed-3, Yamuna Safed-4, Yamuna Safed-5, Yamuna Safed-8, Yamuna Safed-9, Baram Local-06, Jamnagar Local, Mandsaur Local, Ranebennur Local, Ooty Local, GRS-1330, GN14-25, GN14-15, DWG-2 and check DWG-1 were found resistant to purple blotch. Among all the genotypes, Yamuna Safed-3 and Yamuna Safed-2 were proved to be promising genotypes with high bulb yield.

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RESEARCH ARTICLE

EFFECT OF BEST PLANT BIO-REGULATORS AND MICRONUTRIENT FOR ACHIEVING HIGHER YIELD AND QUALITY OF MANGO (*MANGIFERA INDICA* L.) FRUITS CV. AMRAPALI

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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 obtained revealed that the foliar application of GA_3 (40 ppm) + $ZnSO_4$ (1.0%) results in significantly more fruit length, fruit width, fruit weight and pulp per cent with decrease in stone per cent. Increased total soluble solids (^{O}Brix), total sugars (%), ascorbic acid (Vitamin C) were also found maximum with the same treatment *viz.*, pre-harvest application of GA_3 (40 ppm) + $ZnSO_4$ (1.0%) and acidity in the fruit was drastically reduced under this treatment.

Keywords: Mango, GA_3, NAA, Zinc sulphate, Yield, Quality

INTRODUCTION

The mango (*Mangifera indica* L.) 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 covers about 34.90% area and 20.70% production of total fruits cultivated (NHB database 2013-14). The total annual production of mango in India is estimated to be 18431330 mt. and 2515970 ha. cultivated area with 7.3 mt. per ha productivity (NHB database 2013-14). The mango is cultivated in almost all the states of India, like Uttar Pradesh, Andhra Pradesh, Bihar, West Bengal, Karnataka, Gujarat, Maharashtra, Madhya Pradesh, Tamil Nadu, Kerala and Punjab. The maximum area of mango is in Maharashtra (485000 ha.) followed by Andhra Pradesh (304110 ha), whereas, the maximum production (4300980 mt.) and productivity (16.4 mt. / ha) of mango is in Uttar Pradesh, followed by maximum production in Andhra Pradesh (2737010 mt.) and maximum productivity in Jharkhand (10.1 mt. / ha).

Mango is recognized as one of the well accepted fruits all over the world due to its luscious taste, captivating flavour and attractive colour. It plays an important role in balancing diet of human being by providing about 64-66 calories per 100g of ripe fruits. It is a rich source of carbohydrate as well as vitamins A and C. Mango fruit contains 73.0-86.7% moisture, 11.6-24.3% carbohydrate, 0.3-1.0% protein, 0.1-0.8% fat, 0.3-0.7% mineral, 650-25900 μg vitamin ‘A and 3-83mg vitamin ‘C per 100g fruit. Seed kernels also contain 9.5% protein, 8-12% fat, 79.2% starch, 2% mineral matter and 2% fibers.

Mango fruits are considered as excellent table fruit. A variety of products can be prepared from both immature green and ripe fruits. The green mature fruits are used extensively by food processing industry to prepare a wide variety of products such as dried slices, mango powder, pickles and chutneys. Ripe fruits are utilized in preparing squash, nectar, jam, jelly, cereals flakes, custard powder, baby food, toffee etc. Unani physicians hold mangoes in very high esteem because of its many medicinal values. They are used for strengthening the nervous and blood systems, ridding the bloody from toxins and treating anemia. In Ayurveda, dried mango flowers are used to cure dysentery, diarrhea and inflammation of the urinary tract. 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

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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 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.

MATERIALS AND METHODS

The present investigation entitled "Influence of pre-harvest application of plant bio-regulators and micronutrient on fruit set, fruit drop, yield and quality of mango (*Mangiferaindica* L.) cv. Amrapali" 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., to 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 using 3 replications. Spraying of plant bio regulators and micro-nutrient was done at pea stage of fruit set. Spraying of material was done using as pee pneumatic foot sprayer fitted with nozzle. In each spraying, 10 litre solute material per tree as per treatment was used. The observations on each tree were recorded for fruiting behavior, Fruit yield (kg/tree), Fruit length (cm), Fruit width (cm), Fruit weight (g), Pulp (per cent), Peel per cent and Stone per cent. Sampled fruits from each tree were analyzed chemically for recording their quality in terms of Total soluble solids (^{0}Brix), Titratable acidity per cent, Ascorbic acid (mg/100g pulp), Total sugars (%) and TSS: acid ratio. Whole data were analysed character wise by using standard statistical method suggested by Panse and Sukhatme (1985).

RESULT AND DISCUSSION

Data pertaining to the maximum fruit yield per plant (50.95 kg/plant) was recorded with application of GA_3 (40 ppm)+ $ZnSO_4$ (1.0%), which is significantly higher than remaining all other treatments except T_{14} and T_9, which produces 48.95 kg and 47.69 kg/tree, respectively, whereas, the minimum fruit yield per plant was recorded under control (38.86 kg/plant). When the effect of both plant bio-regulators was assessed, it is clearly revealed that GA_3 40 ppm treated plants produced maximum fruit yield per plant (43.10 kg) followed by GA_3 (20 ppm) treated plants (41.67 kg) but they were statistically at par with each other, whereas, minimum fruits yield per plant (40.43 kg) was recorded in NAA 20 ppm treated plants. The maximum fruit length (11.83 cm) was recorded with the application the GA_3 (40 ppm) + $ZnSO_4$ (1.0%) and this fruit length was significantly higher as compared to remaining other treatments except T_9 which is statistically at par (11.05 cm) with GA_3 (40 ppm) + $ZnSO_4$ (0.5%) treated plants, whereas, the minimum fruit length was recorded under control (8.76 cm). Among both plant bio-regulators GA_3 and NAA, applied during experimentation period, maximum fruit length (9.98 cm) was obtained in GA_3 40 ppm treated plants, which is statistically at par with GA_3 20 ppm (9.63 cm), whereas, minimum (9.41 cm) fruit length was recorded in NAA 40 ppm treated plants. The maximum fruit width (7.15 cm) was recorded with application of GA_3 (40 ppm) + $ZnSO_4$ (1.0%) and this fruit width was significantly higher than remaining all other treatments except T_9 (6.98 cm), which is statistically at par with NAA 40 ppm + $ZnSO_4$ (1.0%) treated plants, whereas, the minimum fruit width was recorded under control (4.95cm). Among the both plant bio-regulators GA_3 and NAA tested, significantly maximum fruit width (6.36 cm) was recorded in GA_3 40 ppm treated plants closely followed by GA_3 20 ppm (5.98 cm), whereas, minimum (5.35 cm) fruit width was recorded in NAA 20 ppm treated plants. The maximum fruit weight (247.38 g) was recorded in the fruits which were produced from the plants treated 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_{10} and T_6 which produced 225.45 g and 223.43 g fruit weight, respectively, whereas, the minimum fruit weight was recorded under control (176.79 g). When the effect of both plant bio-regulators is compared, significantly maximum fruit weight (216.25g) was recorded in NAA 20 ppm followed by GA_3 40 ppm (205.29g) treated plants, whereas, the minimum (188.40g) fruit weight was recorded in NAA 40 ppm treated plants. The maximum pulp per cent (71.06%) was recorded with spraying of GA_3 (40 ppm) + $ZnSO_4$ (1.0%) followed by (69.76%) pulp with GA_3 (40 ppm) + $ZnSO_4$ (0.5%) treated fruits and this fruit pulp per cent was significantly higher than remaining all other treatments, whereas, the minimum fruit pulp per cent (61.73%) was recorded under control. Among both plant bio-regulators was compared and observed that the fruits produced from the plants treated with GA_3 40 ppm resulted maximum fruit pulp per cent (66.98%) followed by the NAA 40 ppm (66.37%) treated plants which is statistically at par with each other, whereas, minimum fruit pulp per cent (65.90%) was recorded in NAA 20 ppm treated plants. The minimum peel per cent (12.53%) was recorded in the fruits treated with the pre-harvest application of GA_3 (20 ppm) + $ZnSO_4$ (1.0%) followed by (13.69%) NAA (40ppm) + $ZnSO_4$ (1.0%) treated plants which produced 13.69% peel per cent in fruits, whereas, the maximum fruit peel per cent was recorded under control (17.58%). Effect of both plant bio-regulators was studied it was found that the minimum fruit peel per cent (14.96%) was recorded in GA_3 40 ppm followed by GA_3 20 ppm (15.85%) treated plants, whereas, the maximum (16.85%) fruit peel per cent was recorded in NAA 20ppm treated plants. All plant bio-regulators treatment were statistically at par with each other. The minimum stone per cent (15.97%) was obtained in the plants treated with the spraying of GA_3 (40 ppm) + $ZnSO_4$ (0.5%) and this fruit stone per cent was significantly lower than remaining all other treatments under investigation followed by16.02% with NAA (40 ppm) + $ZnSO_4$ (0.5%) treated plants, whereas, the maximum stone per cent was recorded under control (20.68%). Among the both plant bio-regulators used, NAA 20ppm treated plants produced minimum stone per cent (17.24%) which is statistically at par with NAA 40 ppm (17.52%), treated plants, whereas the maximum (18.05%) stone per cent was recorded in GA_3 40 ppm treated plants. Maximum TSS content (22.10^0Brix) was recorded in the plants when they were treated with GA_3 (40 ppm) + $ZnSO_4$ (1.0%) and this TSS content of fruits was significantly higher as compared to remaining all other treatments followed by 21.54^0Brix with GA_3 (40 ppm) + $ZnSO_4$ (0.5%) treated plants, being statistically at par with each other, whereas, the minimum fruit TSS content was recorded under control (17.98^0Brix). Effects of both plant bio-regulators were compared, it was noted that maximum TSS content (19.53^0Brix) was recorded with GA_3 20 ppm closely followed by the NAA 20 ppm (19.15^0Brix) treated plants, which is statistically at par with each other, whereas, the minimum (18.83^0Brix) TSS content was recorded in NAA 40 ppm treated plants. The minimum titratable acidity content (0.412%) was recorded in the fruits which were sprayed with the application of GA_3 (40 ppm) + $ZnSO_4$ (1.0%) and this titratable acidity content of fruit was significantly lower than remaining all other treatments under investigation, whereas, the maximum titratable acidity content was recorded under control (0.610%). Both the plant bio-regulators were compared, it is clearly noticed that plants treated with GA_3 20 ppm produced significantly minimum titratable acidity content (0.549%) as compared to remaining all other treatments such as GA_3 40 ppm, NAA 20ppm and NAA 40 ppm treated plants which recorded 0.587%, 0.563% and 0.599%, respectively titratable acidity content. Maximum ascorbic acid (34.67 mg/100g pulp) was recorded with the application of GA_3 (40ppm) + $ZnSO_4$ (1.0%), which is significantly higher than remaining all other treatments under investigation, except T_9 and T_{14} which produced 33.83 mg/100g pulp and 32.93 mg/100g pulp, respectively, whereas, the minimum ascorbic acid (27.02 mg/100g pulp) content in fruit was recorded under control. Among both plant bio-regulators used under investigation, the maximum ascorbic acid (31.85 mg/100g pulp) content in fruits was recorded in NAA 40 ppm treated plants closely followed by GA_3 20 ppm (30.93 mg/100g pulp), whereas, the minimum (26.79 mg/100g pulp) ascorbic acid content was recorded in GA_3 40 ppm treated plants. Maximum total sugar content (21.08%) was obtained with the application of GA_3 (40 ppm) + $ZnSO_4$ (1.0%) and this total sugars content of fruit was significantly higher than remaining all other treatments, whereas, the minimum total sugar content of fruit was recorded under control (16.88%). Both the plant bio-regulators tested under experimentation, GA_3 20 ppm treated plants produced maximum total sugars content (18.13%) which is significantly higher than all other plant bio-regulators treatments, whereas, the minimum total sugars content (17.40%) was with NAA 40 ppm treatment. The highest TSS: acid ratio (53.64) was recorded with the application of GA_3 (40 ppm) + $ZnSO_4$ (1.0%) and this TSS: acid ratio of fruits was significantly higher than remaining all other treatments under investigation, whereas, the minimum TSS: acid ratio of fruit was recorded under control (29.47). Among both plant bio-regulators was assessed, it is observed that application of GA_3 20 ppm produced maximum fruit TSS: acid ratio (35.57) closely followed by NAA 20 ppm (34.01), whereas, the minimum TSS: acid ratio (31.43) was recorded in NAA 40 ppm treated plants.

Physical characters of fruit

The spraying of GA_3, NAA and Zinc sulphate are improved fruit characters over control presented in Table-1. These results are in close conformity with the findings recorded by Sarkar and Ghosh (2004) in mango cv. Amrapali, who reported that maximum fruit length and fruit weight with GA_3 at 30 mg/litre and Tripathi and Shukla (2010), who also found increased fruit size with GA_3 at 100 ppm in strawberry. The weight of fruit improved appreciably in all the treatments over control. However, maximum impact was observed with T_{10} **(**GA_3 (40 ppm) + $ZnSO_4$ at 1.0%. This increase in fruit weight by GA_3 application might be due to the accumulation of more food material in fruit trees. Singh *et. al.* (1994) and Tripathi and Shukla (2008) also reported maximum fruit weight, length and diameter with the use of GA_3. The recorded observations pulp, peel and stone per cent clearly indicate that pre-harvest application of GA_3 (40 ppm) + $ZnSO_4$ at 1.0% (T_{10}) resulted in significant increase in pulp per cent and reduction of peel and stone per cent in mango fruit. The minimum pulp per cent and maximum peel and stone per cent was recorded under control. This increase in pulp percentage may be due to more absorption of water, plant bio-regulators and micronutrient which increase the volume of inter-cellular spaces in the pulp. These results are in accordance with the reports of Vejendla *et al.* (2008) who found higher pulp in mango cv. Amrapali with the spraying of $ZnSO_4$ (0.75%) and also Moazzam *et al.* (2011) who noted maximum pulp weight and less stone weight in comparison to control with the foliar application of (0.4%) $FeSO_4$ + (0.8%) H_3BO_3 + (0.8%) $ZnSO_4$.

Chemical characters of fruit

Data furnished in Table-2 revealed that application of GA_3, NAA and Zinc sulphate are improved fruit quality Total soluble solids (TSS) or ascorbic acid and TSS: acid ratio over control. The maximum accumulation of total soluble solids (TSS) content in mango fruits was recorded with GA_3 (40 ppm) + $ZnSO_4$ (1.0%), while minimum under control. This increase in total soluble solids contents of fruits may be due to the fact that plant bio-regulators and micronutrient play an important role in the photosynthesis which ultimately lead to the accumulation of carbohydrates and ultimately increase of TSS content of mango fruit. The adequate amount of zinc improved the auxin content and it also acted as catalyst in oxidation process. The results are in close conformity with the finding of Sarkar and Ghosh (2005), Vashistha *et al*. (2010**)** and Shrivastava and Jain (2006) in mango. The use of different plant bio-regulators and micronutrient treatments significantly influenced the acidity percentage in mango fruits. The minimum acidity percentage was noted with GA_3 (40 ppm) + $ZnSO_4$ (1.0%), whereas, the maximum in control. Acidity content of fruits decreased with the foliar application of plant bio-regulators and micronutrient, which might be due to an increase in translocation of carbohydrates and increase in metabolic conversion of acids to sugars by the reaction involving reversal of glycolytic path way and used in respiration or both. Another reason for reduction in acidity per cent in plant bio-regulators and micronutrient treated fruits, might be the early ripening of fruits which was induced by the plant bio-regulators and micronutrient spray due to which degradation of acid might have occurred. These results are in accordance to the reports of Shrivastava and Jain (2006), who also found significant reduction in acidity content in mango cv. Langra with urea at 2% and GA_3 (100 ppm) and Tripathi and Shukla (2010) in strawberry. Ascorbic acid content of fruits was significantly influenced by plant bio-regulators and micronutrient spraying as compared to control. Significantly maximum amount of ascorbic acid was found with GA_3 (40ppm + $ZnSO_4$ (1.0%), whereas, minimum was recorded with control. The increased ascorbic acid content of fruit juice was due to increase in the synthesis of catalytic activity by enzyme and coenzyme, which are represented in ascorbic acid synthesis. The adequate amounts of zinc improve the auxin content and it also acts as catalyst in oxidation process. These findings are in closely accordance with the results of Rajak *et al.* (2010), who reported maximum ascorbic acid content (mg/100 g pulp) in fruits with $ZnSO_4$ (0.6%), and Borax (0.8%) and minimum under control in mango cv. Amrapali fruits. Tripathi and Shukla (2008) in strawberry also found increased ascorbic acid content with GA_3 treatment. The similar pattern in respect to total sugars content and TSS/acid ratio was also recorded as they were also influenced by plant bio-regulators and micronutrient. The highest total sugars and TSS/acid ratio content was recorded with GA_3 (40 ppm) + $ZnSO_4$ (1.0%) and minimum in control. This increase in total sugars content and TSS/acid ratio may be due to the fact that zinc works as stimulator of amino acids and appears to be helpful in the process of photosynthesis and in accumulation of carbohydrates which ultimately help in the translocation of more sugar and TSS to the fruits. It has been reported that there is a greater conversion of starch into sugar (source to sink) in the presence of these plant bio-regulators and micronutrient. The results are in accordance to the finding of Kumar *et al.* (2011), who reported maximum total sugars in mango cv. Amrapali with 2% urea + $ZnSO_4$ (1.0%).

However, maximum TSS/acid ratio was obtained with 2% urea + $ZnSO_4$ (0.5%) and Bhowmick *et al.* (2012), who noted maximum total sugars and non-reducing sugar with the application of $ZnSO_4$ (1.0%) in mango cv. Amrapali.

Table 1. Effect of pre-harvest application of plant bio-regulators and micronutrient on physical characters of mango fruits.

Treatments	Fruit yield per/plant (kg)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Pulp (%)	Peel (%)	Stone (%)
T_1-GA_3 (20 ppm)	41.67	9.63	5.98	195.56	66.24	15.85	17.90
T_2-GA_3 (40 ppm)	43.10	9.98	6.36	205.29	66.98	14.96	18.05
T_3-NAA (20 ppm)	40.43	9.41	5.35	216.25	65.90	16.85	17.24
T_4-NAA (40 ppm)	41.63	9.59	5.55	188.40	66.37	16.10	17.52
T_5-$ZnSO_4$ (0.5%)	37.23	9.88	5.78	209.87	65.36	16.99	17.64
T_6-$ZnSO_4$ (1.0%)	39.39	9.73	6.10	223.43	64.95	16.43	18.61
T_7-GA_3 (20 ppm) + $ZnSO_4$ (0.5%)	44.92	10.19	6.05	202.53	68.22	15.10	16.67
T_8-GA_3 (20 ppm) + $ZnSO_4$(1.0%)	46.13	10.46	6.47	204.26	68.62	13.69	17.68
T_9-GA_3 (40 ppm) + $ZnSO_4$ (0.5%)	47.69	11.05	6.93	225.45	69.76	14.26	15.97
T_{10}-GA_3 (40 ppm) + $ZnSO_4$ (1.0%)	50.95	11.83	7.15	247.38	71.06	12.53	16.40
T_{11}-NAA (20 ppm) + $ZnSO_4$ (0.5%)	45.17	10.07	6.10	208.32	67.68	14.52	17.79
T_{12}-NAA (20 ppm) + $ZnSO_4$ (1.0%)	46.89	10.02	6.63	219.76	68.27	15.35	16.87
T_{13}-NAA (40 ppm) + $ZnSO_4$ (0.5%)	47.03	10.12	6.69	207.85	68.95	15.02	16.02
T_{14}-NAA (40 ppm) + $ZnSO_4$ (1.0%)	48.95	10.16	6.98	217.95	69.59	14.10	16.30
T_{15}-Control (water spray)	38.86	8.76	4.95	176.79	61.73	17.58	20.68
S. E. m ±	0.882	0.348	0.146	3.795	1.303	0.485	0.120
CD at 5%	2.569	1.013	0.424	11.050	3.795	1.406	0.351

Table 2. Effect of pre-harvest application of plant bio-regulators and micronutrient on quality parameters of mango fruits.

Treatments	TSS (^{0}Brix)	Acidity (%)	Ascorbic acid (mg/100g pulp)	Total sugars (%)	TSS: acid ratio
T_1-GA_3 (20 ppm)	19.53	0.549	29.93	18.13	35.57
T_2-GA_3 (40 ppm)	18.95	0.587	30.38	17.43	32.28
T_3-NAA (20 ppm)	19.15	0.563	28.62	17.79	34.01
T_4-NAA (40 ppm)	18.83	0.599	29.99	17.40	31.43
T_5-$ZnSO_4$ (0.5%)	19.65	0.545	28.92	18.22	36.05
T_6-$ZnSO_4$ (1.0%)	19.93	0.537	29.85	18.43	37.11
T_7-GA_3 (20 ppm) + $ZnSO_4$ (0.5%)	20.25	0.506	30.78	18.97	40.01
T_8-GA_3 (20 ppm) + $ZnSO_4$ (1.0%)	20.45	0.502	31.19	19.21	40.73
T_9-GA_3 (40 ppm) + $ZnSO_4$ (0.5%)	21.54	0.441	33.83	20.19	48.84
T_{10}-GA_3 (40 ppm) + $ZnSO_4$ (1.0%)	22.10	0.412	34.67	21.08	53.64
T_{11}-NAA (20 ppm) + $ZnSO_4$ (0.5%)	20.05	0.511	31.08	18.80	39.23
T_{12}-NAA (20 ppm) + $ZnSO_4$ (1.0%)	20.87	0.498	31.49	19.49	41.90
T_{13}-NAA (40 ppm) + $ZnSO_4$ (0.5%)	20.99	0.499	32.15	19.58	42.06
T_{14}-NAA (40 ppm) + $ZnSO_4$ (1.0%)	21.10	0.487	32.93	19.72	43.32
T_{15}-Control (water spray)	17.98	0.610	27.02	16.88	29.47
S. E. m ±	0.127	0.017	0.579	0.146	0.606
CD at 5%	0.371	0.051	1.679	0.426	1.766

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RESEARCH ARTICLE

CROPPING PATTERN AND ECONOMICS OF CEREALS PRODUCTION IN DIVERSE SEASONS OF UTTARAKHAND HILLS

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Abstract: This study was aimed at identifying cropping pattern in Uttarakhand state and analyzing cost, return and profitability of cereals in different seasons. The study is based on the both primary and secondary sources and has made use of the farm level cross-sectional data collected through multistage random sampling technique from 200 sample farmers belonging to different hill altitudes. To estimate cost major inputs like labor, farmyard manure, fertilizer, seeds, animal feed etc were identified and valued at the prevailing market rates. Returns were estimated by multiplying quantities produced of particular crop and current market prices. Results indicated a cropping intensity of 188% and the cereal crops accounted for around 70% of the gross cropped area. Wheat emerged as the main food grain crop in the study area with its percentage share of 26.98% in the gross cropped area, while paddy (24.21%) was the second major cereal crop in the study area. The cost of cultivation of cereals summer season (₹ 11704/acre) was slightly less than that of cereals in winter season (₹ 11866/acre). Per acre net return from cereals was found to be higher for winter season (₹ 11237.7/acre) when compared to wheat summer season (₹ 8420.37/acre).

Keywords: Cereals, Cropping pattern, Cost of cultivation, Net returns, Seasons

INTRODUCTION

The cropping pattern in India has undergone considerable changes over time. As the cultivated area remains relatively constant, the increase in demand for food because of increased population and urbanization has necessitated crop intensification and substitution of food crops with commercial crops. During 2011-12, there was a record for the production of food grains in India at 259.32 million tonnes, of which 131.27 million tonnes was during Kharif season and 128.05 million tonnes during the Rabi season. Of the total food grains production, the production of cereals was 242.23 million tonnes and pulses 17.09 million tonnes. A number of studies reveal that improved production of agricultural commodities through green revolution resulted in lower incidences of rural poverty (Ahluwalia, 1978; Narayanamoorthy, 2004; Hussain and Hanjra, 2003; 2004), wage rate improvements and in creating employment opportunities in the rural areas mainly for the landless labourers (Saleth, *et al*., 2003. Despite all these attainments, the farm sector in India is not free from many upsetting facets. Farmers' suicides, indebtedness, poor returns over cost of cultivation, non-remunerative prices for crops and crop failures etc. are the prominent features of India's agriculture today (Pushpa et al., 2017). Why this is happening in India still remains a concern. Some studies have observed that stagnation in real income, higher cost of cultivation through relatively higher rise in input prices than the prices of the agricultural produce could be the reasons for farmers suicides (Kalamkar and Narayanamoorthy, 2003; Narayanamoorthy 2006; Deshpande and Arora, 2010; Sainath, 2010).

Hilly states in particular, confront multiple risks and uncertainty due to undulated topography, scattered land holdings, low mechanization, soil erosion and extreme weather conditions, etc. Returns from crop cultivation are vital not only for the survival of the farmers but also to facilitate reinvestment in agriculture. The Situation Analysis Study of Indian Farmers conducted by the National Sample Survey Organization (NSSO) in 2006 has revealed that about 27 per cent of the farmers do not like farming because of its less profitability; and if a chance is given, nearly 40 per cent farmers would prefer to take up livelihood activities other than farming (Kumar *et al.*, 2006).

Jammu and Kashmir, Himanchal Pradesh and Uttarakhand are the three major northern hilly states of India. Out of the three hilly states Uttarkhand was purposively selected for the study due to following reasons:

- Uttarakhand have higher rural (11.62per cent) and urban (10.48per cent) below poverty line (BPL) percentage (RBI, 2012).
- The state performs worse (6^{th} rank) than Himanchal Pradesh (8^{th} rank) and Jammu and Kashmir (10^{th} rank) in the development disability index (NIPFP report, 2013).

The economy of Uttarakhand is predominantly agrarian where only 14 percent of the total land is under cultivation and about 65 percent of population depends on agriculture for their livelihood. State's land holding pattern is also not promising, nearly 75 percent population has marginal

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land holding (Less than 1 hectare). Furthermore, cropping pattern in the state is dominated by traditional and low yielding crops leading to continued vicious cycle of low production. Being a state with diverse agro-climatic endowments, conditions under which agriculture is carried out differ remarkably across areas. Broadly the plains and hills present different scenario for agriculture in Uttarakhand. However, the development has predominantly been in the plain areas and the hilly areas have been left behind. The hilly regions are lacking behind in terms of infrastructure, i.e. electricity, roads and irrigation facilities. Not many studies have detailed analysis of the profitability of different crops in relation to the cost of cultivation. Therefore, an attempt has been made in this study to find out the cost of cultivation and profitability of major cereal crops in hilly region of country.

MATERIAL AND METHODS

A Multistage random sampling technique was used for the study. In the first stage two districts, *viz.*, Champawat and Nainital were chosen from the state randomly. Champawat district consists of four developmental blocks out of which two blocks namely; Pati and Lohaghat were selected in the second stage, while two blocks i.e. Okhalkanda and Ramgarh were chosen from eight development blocks of Nainital district at random. At the final stage two villages clusters each from low hills and high hills were selected randomly from each block. A complete list of all the farmers in each selected village was prepared and twenty five farmers from each village were selected randomly. Therefore, the study was based on the findings from 200 sample farmers selected in the study area.

Database

The required primary data were collected from selected farmers using pre-structured schedule through personal interviewing method for the agricultural year 2017-18. Information related to various socio-economic parameters of the households like, caste and religion, size and composition of family, education level, principal and subsidiary occupations, land holding, livestock possession, asset possession, income and expenditure pattern, employment pattern and earning from different sources, consumption pattern etc., were collected from the primary sources. Secondary data was also collected from different government offices like District Block Development Offices, Office of Chief Agricultural Officer of Nainital and Champawat districts, District Statistical Offices, as well as from different government publications and websites. Besides, some basic information was also collected from different journals and publications.

Analytical Framework

Farm income was obtained by broadly estimating costs and returns from various crop and livestock enterprises as a whole. To get the net income, total farm income was subtracted from total cost.

Cost of cultivation includes operational costs, material costs and other costs in crop production. In operational costs, the cost of hiring human labour, machine power, bullock charges have been estimated by the prevailing rate at that particular period of time in the study area. Hired labour charge at the actual wage paid in cash and other kind of payments were also converted into monetary terms at the existing price. Imputed value of the family labour was also calculated using the prevailing wage rate in the study area. In case of bullock, tractor and other machinery and hiring charges were applied to these as the cost for those who don’t own them, whereas the cost of fuel, repairing and maintenance cost were calculated for those who own them. In case of material costs; cost of seeds, manure, chemicals, fertilizers irrigation charges were calculated at prevailing price at the time of application per acre basis for selected farmers. Owned seed was priced as the prevailing seed price in the study area. Rental value of the land prevailed in the study area during study period was taken.

On the other hand, returns were estimated by multiplying quantities produced of particular crop and prevailing market prices.

RESULTS AND DISCUSSION

Occupational structure of households

In determining the main and subsidiary occupations, the source from which the household earned the highest income was considered as the main occupation and rest others were considered as subsidiary occupations. Details about the main and subsidiary occupations of the respondents are presented in Table 1.

Table 1. Occupational distribution of households

Average number of livelihood activities per HH	**3.45**		
Livelihood activities	**Households**		
	Total	**Main**	**Subsidiary**
Agriculture	200 (100.00)	31 (15.50)	169 (84.50)
Livestock Rearing	197 (98.50)	1 (0.50)	196 (98.00)

Agriculture + Livestock Rearing	45 (22.50)		
Agricultural laborer	14 (7.00)	10 (5.00)	4 (2.00)
Govt. Job	54 (27.50)	49 (24.50)	5 (3.50)
Private Job	58 (29.00)	41 (20.50)	17 (7.50)
Self Employed/Business	64 (32.00)	52 (26.00)	12 (7.50)
Pension	69 (34.50)	16 (8.00)	53 (26.50)
Gender-wise participation in farming Activity			
Male	114 (57.00)		
Female	200 (100.00)		
Average age of individuals who are engaged (Yrs)			
In Farming	43.41		
In Other livelihood activities	34.69		

Note: Figures in parentheses indicate per cent to total households.

It is evident from the table that despite having 100 per cent participation of households in agriculture, earning wise it was main occupation only for 15.50 per cent of the households while for 84.50 per cent households it was observed as subsidiary occupation. It is important to notice that livestock rearing was only the subsidiary occupation for almost all households. Only 22.5 per cent households pursued agriculture + livestock occupation solely. Average number of livelihood activities per household was 3.45 in the study area. Crop production activity was undertaken by each and every sample farm households with the variation in the household income shared by crop production. Livestock activities were also common as most of the sample farm households (98 %) were found to be engaged in livestock rearing.

Self employment in the form of shop keeping, account keeping and driving etc. were pursued by most of the households and formed main occupation for around 26 per cent households while was subsidiary occupation for 7.5 per cent of the same. Other predominant occupations for households were private salaried jobs particularly in factories (main 20.5 % and subsidiary 7.5 %), and government services (main 24.5 % and subsidiary 3.5%) etc. Construction workers, aaganwadi workers, bhojan matas, street hawkers, housemaids were the common type of occupations prevalent among sample households. About 35 per cent households received pension of which for 8 per cent of households it was main source of livelihood.

It is very interesting to note that female participated predominantly (100 %) in agriculture while male participation was considerably low i.e. only 57 per cent (Table 1). Reason might be less productive agriculture made them to move out and find other sources of earning while major family responsibilities and social constraints made women stay at home and continue farming. The average age of individuals who were engaged in agriculture was 43.41 years while those individuals who were engaged in other livelihood activities it was 34.69 years. It shows that there may be instances of disinterest of the younger class of population in agriculture owing to many reasons like lesser returns from agriculture, imitation of urban culture etc.

Cropping pattern followed by farm households

Cropping pattern refers to the yearly sequence and spatial arrangement of crops or of crops and fallow on the given area. It can be said the gross cropped area under various crops during an agricultural year. It is a dynamic concept as none cropping pattern can be said to be ideal forever in a particular region. It changes with space and time to meet farm household's requirements and is governed largely by the physical as well as cultural and technological factors. In the present sub section the overall cropping pattern followed by different farm households in the study region is outlined. Table 2 elicits the details of cropping pattern in the study area.

It is evident from the table that cereals occupied the major share of land both in summer and winter seasons. This share was about 34 per cent and 31 per cent of gross cropped area respectively. In summer season paddy was cultivated in 24.21 per cent and coarse cereals (millets) were grown in 9.99 per cent of the gross cropped land. The major cereals grown in winter season were wheat and ragi of which wheat occupied 26.98 per cent of gross cropped area. The share of coarse cereals was very less i.e. 3.84 per cent in winter season.

Table 2. Cropping pattern in the study area

Crop	Area in Acre (acre)	Percentage
Kharif Season (Summer)		
Cereals	**4.45 (0.22)**	**34.20**
• Paddy	3.15 (0.16)	24.21
• Coarse Cereals (Sorghum, pearl Millet)	1.30 (0.07)	9.99
Pulses	**1.58 (0.08)**	**12.14**
• Horsegram	0.75 (0.04)	5.76
• Soybean (Black)	0.45 (0.02)	3.46
• Rajma	0.38 (0.02)	2.92
Vegetables	**0.88 (0.04)**	**6.76**
• Chilli	0.70 (0.03)	5.38
• Pumpkin	0.08 (0.00)	0.61
• Turmeric	0.10 (0.01)	0.77
Total cropped area	**6.91 (0.35)**	
Rabi + Zaid Season (Winter)		
Cereals	**4.01 (0.20)**	**30.82**
• Wheat	3.51 (0.18)	26.98
• Coarse Cereals (Ragi, Barley)	0.50 (0.02)	3.84
Pulses	**1.21 (0.06)**	**9.30**
• Lentils	0.75 (0.04)	5.76
• Gram	0.46 (0.02)	3.54
Vegetables	**0.88 (0.04)**	**6.76**
• Potato	0.36 ((0.02)	2.77
• Onion	0.31 (0.01)	2.38
• Radish	0.21 (0.01)	1.61
Fallow	**0.51 (0.02)**	**3.92**
Total cropped area	**6.10 (0.30)**	
Gross cropped area	**13.01 (0.65)**	**100**
Cropping Intensity	**188.28%**	

Figures in parentheses indicate values in hectare **(1 acre=0.05 acre)**

Pulses occupied around 12 per cent and 9 percent of gross cropped area in summer and winter season respectively. Among pulses horsegram, black soybean and rajma were major pulses grown in summer season and covered 5.76 per cent, 3.46 per cent and 2.92 per cent of gross cropped land, while in winter season lentils and gram occupied 5.76 and 3.54 per cent of the gross cropped area respectively. Table further reveals that the share of vegetables remained same in both the seasons and was grown in 6.76 per cent of the gross cropped land. In summer season chilli occupied the major share of land (5.38

%) among vegetables followed by turmeric (0.77 %) and pumpkin (0.61 %). In winter season potato, onion and radish were major types of vegetables grown and occupied 2.77 per cent, 2.38 per cent and 1.61 per cent of gross cropped land respectively.

Around 4 per cent land was left as fallow land in winter season thus giving the average gross cropped area of 0.65 acres in the study area in one agriculture year. Cropping intensity was observed to be high i.e. 188.28 per cent in the study area.

Economics of cereal production in the study area

Table 3 depicts cost of cultivation and returns from the cereal crops produced in the study area. For estimating the cost major inputs were identified under three broad categories viz., labour cost, material cost and rental value of owned land. Labor cost was further divided into three subgroups namely; family labour, hired labour and bullock labour. Material cost was also divided into two subgroups i.e. seed cost and cost of manures, fertilizers and plant protection chemicals taken together. Owned land was valued at prevailing rental rates of agricultural land in the study area.

Table 3 reveals that the average imputed cost of family labour incurred on different operations involved in cereal production was 42.51 per cent and 27.81 per cent in summer and winter season respectively. As paddy is grown in kharif/summer season, more labour is required for various additional operations involved in paddy cultivation like transplanting, puddling, land preparation etc in comparison to wheat, which is grown in winter season. The results were in consonance of the study conducted by Singh *et al*. (2013) who reported that share of human labour in gross cost was 45 per cent in case of inbred variety of rice production in Uttarakhand.

Table 3. Cost of cultivation & returns from various Crops (Rs/Acre)

Particulars	**Kharif Season (Summer)**	**Rabi + Zaid Season (Winter)**
Family	Cereals	Cereals
Labor Cost		
Family	4975.60 (42.51)	3300.40 (27.81)
Hired	104.60 (0.89)	157.20 (1.32)
Bullock	1930.00 (16.49)	2362.40 (19.91)
Total labour cost	**7010.20 (59.89)**	**5820.00 (49.04)**
Materials Cost		
Seed	618.20 (5.28)	872.20 (22.94)
Fertilizers + Manure+ PPC	2076.00 (17.74)	3173.60 (26.74)
Total material cost	**2694.20 (23.02)**	**4045.80 (34.10)**
Rental value of owned land	**2000 (17.08)**	**2000 (16.85)**
Total Cost	**11704.40 (100)**	**11865.8 (100)**
Yield (Kg/Acre)	920.20	1169.80
Price/ kg	21.87	19.75
Total Returns	**20124.77**	**23103.5**
Net Returns	**8420.37**	**11237.7**

It was further observed from the table that average expenditure incurred on bullock labour was around 16 per cent and 20 per cent in summer and winter season respectively. Overall average cost of labour incurred on cereal production was ₹ 7010.2 per acre i.e. 59.89 Per cent and ₹ 5820 per acre i.e. 49.04% of total cost of cultivation of cereals in summer and winter seasons respectively. Pant and Srivastava (2014) reported similar share of labour cost i.e. 55.30 % to total cost while calculating economics of millets in Uttarakhand state. Other studies (Sureshkumar *et al*.; 2014, Verma *et al*.; 2016) revealed that this labour cost share varied region wise. In Madhya Pradesh share of labour cost in wheat production accounted for about 26 per cent of total cost, while in Gujarat it was 27.70 per cent. Reasons of the more labour cost share in hills may be, less or almost nil mechanization of agricultural operations in hilly areas, which makes crop cultivation labour intensive and thus results in more labour cost share.

Seeds and manure constituted the major components of material cost in the study area. Material cost accounted for 23.02 per cent in the cost of cereal cultivation with its absolute value of ₹ 2694.20 per acre in summer and 34 per cent with its absolute value of ₹ 4045.80 per acre in winter season.

The per acre rental value of land was ₹ 2000. Large proportion of fixed cost was on account of rental value of owned land constituting 17.08 per cent and 16.85 per cent of total cost of cereal cultivation in summer and winter seasons correspondingly.

Overall magnitude of cost of cereal cultivation was ₹ 11704.40 per acre in summer season and ₹ 11865.80 per acre in winter season.

Table 3 also gives details about gross returns and net returns for all groups of crops. Total returns were estimated by multiplying quantities produced of particular crop and prevailing market prices. It is observed from the table that productivity of cereals was higher in winters i.e. 1169.80 kg per acre, the corresponding figures for summer season were 920.20 kg. Average total returns from cereal production obtained were ₹ 20124.77 per acre in summers and ₹ 23103.55 per acre in winter season.

Finally the net returns were obtained to determine the actual earning of sample households from crop production. The average net returns from the production of cereals amounted to ₹ 8420.37 per acre in summer season and ₹ 11237.75 per acre in winter season.

CONCLUSION

The study was confined to major cereal crops grown in Uttarakhand hills. Despite 100 per cent participation of households in agriculture, earning wise it formed main occupation only for 15.50 per cent of the households while for 84.50 per cent households it was observed as subsidiary occupation. It is important to notice that livestock rearing was only the subsidiary occupation for almost all households. The selected crops that were taken together accounted for around 70% of the gross cropped area. The study is based on the information available by both primary and secondary sources and has made use of the farm level cross-sectional data collected from 200 sample farmers of different hill altitudes. Wheat emerged as the main food grain crop in the study area with its percentage share of 26.98% in the gross cropped area, while paddy (24.21%) was the second major crop in the study area. The cost of cultivation of cereals summer season (₹ 11704/acre) was slightly less than that of cereals in winter season (₹ 11866/acre). Per acre net return from cereals was found to be higher for winter season (₹ 11237.7/acre) when compared to wheat summer season (₹ 8420.37/acre).

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RESEARCH ARTICLE

GROWTH AND YIELD OF CITRONELLA (*CYMBOPOGON WINTERIANUS*) AS INFLUENCED BY DIFFERENT RESIDUAL FERTILITY LEVELS AND INTERCROPPING WITH LENTIL AND LINSEED

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Abstract: A field experiment was conducted at, student Instructional Farm (SIF) Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) India during rabi season 2013-14. with an object to find out the effect on growth parameters and yield attributes of linseed and lentil as intercrops, with citronella (Cymbopogon winterianus). The experiment was laid out in randomized block design with 9 cropping system with different combination [sole citronella, sole linseed, sole lentil, citronella + linseed (100%), citronella + linseed (75%), citronella + linseed (50%), citronella + lentil (100%), citronella + lentil (75%), citronella + lentil (50%) each replicated four times (once in each replication). The citronella sole cropping system gave significantly the highest citronella equivalent oil yield than other cropping systems. Citronella + Linseed (50%) treatment ranked next in order of merit, proving significant better than other cropping system. Citronella + Lentil (100%) ranked next in order of merit, proving significant superior over other cropping system. Citronella sole brought about 57.35 (30.30%), 61.63 (33.32%), 84.56 (52.04%), 85.35 (53.09%), 90.45 (57.93%), 92.69 (60-63%), 179.27 (266.37%) and 192.80 (258.56%) lit/ha higher citronella equivalent oil yield than citronella + linseed (100%), citronella + linseed (75%), citronella + linseed (50%), citronella + lentil (100%), citronella + lentil (75%), citronella + lentil (50%), linseed sole and lentil sole respectively. LER was more than sole crops which showed and advantage of intercropping over sole system in terms of the use of environment resources for plant growth and development. LER values in citronella + linseed (75%) and citronella +linseed (100%) intercropping system was 1.34.

Keywords: Residual fertility, LER, Citronella, Growth parameters,Yield attributes

INTRODUCTION

In today's agriculture diversification and intensification of crop and their combination and sequence both in space and time with new adoptable and remunerative crops and their species has become absolutely necessary as the present food base has been narrowed down coupled with effect of climate change making it prone to frequent crop failures. Today intercropping with various non-exploited crops are gaining importance due to their adoptability to changing climatic conditions prevailing in the region and for achieving higher returns under adverse conditions.

Citronella (*Cymbopogon winterianus*) is an aromatic crop belonging to family Poaceae. Citronella is a perennial grass and is propagated by vegetative slips. It grows well under varying soil conditions. Citronella oil has great demand in India. According to FFDC (Fragrance and Flavour Development Centre, Govt. of India, Kannauj) the demand of citronella oil is 620 tonnes per year but the production 480 tonnes per year in India. The country facing deficit of 140 tonnes per year (Anon., 2011-2012). The increasing importance of natural extracts in recent time has opened up new vistas for green revolution beyond their wide spread use as flavors and fragrance ingredients. Citronella oil is a raw material for production of geranial, citronellal and other similar high value perfumery bases. Citronella oil is widely used in scented soaps, sprays, deodorants, detergent, polishes, mosquito repellents etc. The present experiment was carried out with an object to study about the growth parameters and yield attributes of Citronella (*Cymbopogan winterianus*) as Influenced by different residual fertility levels and Intercropping with lentil and linseed.

MATERIALS AND METHODS

A field experiment was conducted during rabi season, 2013-14 at Students Instructional Farm (SIF), C.S. Azad University of Agriculture and Technology, Kanpur to study the Growth and Yield of lentil and linseed as Influenced by Recommended Doses of Fertilizer and Intercropping with citronella (*Cymbopogan winterianus*). The experiment was laid out in Randomized block design with 9 treatment of cropping systems with 3 residual fertility levels(RFL) i.e. [Sole citronella, Sole Lentil, Sole Linseed, Citronella + lentil (100%RFL), citronella + lentil (75%RFL), citronella + lentil (50%RFL), citronella + Linseed (100%RFL), citronella +

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Linseed (75% RFL), citronella + Linseed (50% RFL)], were replicated in three time. The soil of experimental field was sandy loam, slightly alkaline in nature. The soil is low in organic carbon and available nitrogen (260 kg/ha), medium in available phosphorus (17.55kg/ha) and potash (175 kg/ha). Root slips of Citronella variety BIO-13 were used for transplanting. After removing upper sheath the root slips was transplanted in line on 30 July, 2010 at a spacing of 60 × 60 cm. The row ratio of 2:2 was maintained in citronella intercrop plots. Seed of linseed cv. Laxmi was used @ 25 kg/ha. The crop was sown with the help of Desi plough in line on 28 October, 2013 at a spacing of 25 × 5 cm. The total number of row in sole and intercrops are 20 and 10 respectively. Seed of Lentil cv. K-75 was used @ 30 kg/ha. The crop was sown with the help of Desi plough in line on 2 November, 2013 at a spacing of 30 × 30 cm. The total number of rows in sole and intercrops are 20 and 10 respectively. In order to determine the effect of different treatments, a number of observation on growth characters, yield contributing characters and yield of crops (Herbs, grain, straw etc.), oil content in citronella and weed population were recorded at different stages of crop growth. It was not possible to study the all characters of individual plants, 5 sample plants from main and intercrops of each treatment (main and intercrop)were selected randomly and tagged for further study. All the observations taken are categorized as pre harvest studies and post harvest studies

(A) Observations for Citronella crop:-

(1) Pre - harvest observation: Prior to harvesting of citronella observations for plant population, plant height, number of tillers per plant, leaf length and leaf width has been taken.

(2) Post harvest studies: After harvesting of citronella crop observations for herbage yield and steam distillation has been carried out.

(B) Observations for Lentil:-

All the observations taken during experimental period are categorized in to the following groups:

Pre Harvest studies:- Prior to harvesting of lentil observations of plant population per meter square at 30 DAS, 60 DAS and at maturity, plant height at 30 DAS, 60 DAS and at maturity, number of branches per plant, number of pods per plant(5 selected plants), number of grains per pod(calculated by dividing the total number of grains from 5 plants by the total number of filled pods from these plants.), weight of pods per plant(total pods were collected from the sample plants and their pods were weighted to work out for statistical analysis.) and test weight has been taken during experiment.

Post harvest studies:- Observations for biological yield, grain yield and straw yield of lentil was taken. The produce of individual net plots was weighed before threshing to record the biological yield under different treatments. The produce of each net plot was beaten through wooden stick by manual labour and grains were separated from the material through winnowing. The grains yield was recorded in kg per plot. Straw yield was found out by subtracting the grain yield from biological yield of each plot. Later on biological yield, grain yield and straw yield converted in to quintal per hectare, through multiplying factors.

(C) For Linseed

All the observations taken in each treatment during experimental period are categorized below:-

Pre harvest studies:- Growth characters of linseed crop such as plant population. The plant population of each treatment was recorded twice after first thinning and at harvest stage. For this purpose, one meter scale was placed randomly in 3 places in each plot after thinning and at harvest stage. In marked places, plants were counted for both initial and final plant population. The total sum of plant number of 3 places was divided by 3 to get number of plant population per running meter**.,** plant height of 5 tagged plants at 30 DAS, 60 DAS and at maturity, number of branches per plant of 05 selected plant and average number of branches calculated per plant on mean basis for statistical analysis, number of capsules per plant. Total numbers of capsule were counted from each selected plants and average value was worked out for statistical analysis. Number of grains per capsule (total numbers of capsule were collected randomly from the sample plants and their grains were counted) and test weight have observed during growth period of linseed crop.

Post harvest studies: Observations for biological yield, grain yield and straw yield of lentil was taken. The produce of individual net plots was weighed before threshing to record the biological yield under different treatments. The produce of each net plot was beaten through wooden stick by manual level and grains were separated from the material through winnowing. The grains yield was recorded in kg per plot after weighed. Straw yield was found out by subtracting the grain yield from biological yield of each plot. Later on biological yield, grain yield and straw yield converted in to quintal per hectare.

Harvest index (%)

The recovery of grain in total weight of produce was considered as harvest index which was calculated in percentage and expressed as absolute figures. The harvest index (HI) of Lentil and Linseed of each crop/plot was calculated by using the following formula:-

$$\textbf{Harvest index (H.I.)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Land Equivalent Ratio (LER)

Land equivalent ratio is the relative land area under sole crops i.e. required to produce the yield achieved in inter cropping. In the present experiment the LER was estimated by following formula/equations.

$$\text{(i) LER for Linseed} = \frac{\text{Yield of citronella in inter cropping}}{\text{Yield of citronella in sole cropping}} + \frac{\text{Yield of Linseed in inter cropping}}{\text{Yield of Linseed in sole cropping}}$$

$$\text{(ii) LER for Lentil} = \frac{\text{Yield of citronella in inter cropping}}{\text{Yield of citronella in sole cropping}} + \frac{\text{Yield of Lentil in inter cropping}}{\text{Yield of Lentil in sole cropping}}$$

For determining the significance of difference caused by different treatments data were subjected to statistical analysis by using ANOVA.

RESULTS AND DISCUSSION

Effect of different treatments on growth characters and yield attributes of the main crop citronella:

Growth characters:

Data recorded regarding to leaf length and number of tillers per plant at 8th cutting of citronella of the 5th and 6th year is presented in Table 1 showed that highest leaf length (72.45 cm) and number of tillers (95.34 cm) was recorded in Citronella sole crop which was significantly superior over all the treatments. Such higher growth performance in sole crop as compared to intercropping system has also been observed by Ram et al. (2000) and Patra et al. (2005). It is also clear from the table that next to citronella sole, among the intercropping fertility level treatment C:Li (75%) and C:L (75%) were letter than 100% are 50% fertility level in relation to leaf length. But in case of number of tiller, the highest number of tillers/plant after 8th cutting was obtained in 50% fertility level of both intercrops which was statistically at par. Sole Citronella recorded higher values for herbage yields than their intercropping with linseed and lentil. This may be optimum spacing available for the plant. The higher growth performance in sole crop as compared to intercropping system has also been observed by Patra et al. (2005). These results of experiments are in close conformity with the findings of Sher et al. (2008) also.

Yield characters

Data presented in table 1 regarded herbage yield and oil yield indicated that there are significantly difference have been recorded in yield characters. The highest herbage yield recorded in citronella sole which was (196.30 q/ha) and oil yield (165.36 lit/ha) was significantly superior over rest of the treatments, under 100% fertility level. Among the intercropping treatments there was no significance difference in respect of herbage and oil yield under different residual fertility level.

Citronella equivalent yield:

The data pertaining to Citronella yield and Citronella equivalent yield have been given in Table 2. Results indicate that different cropping systems were found to exhibit significantly variations in Citronella equivalent oil yield. The citronella sole cropping system gave significantly the highest citronella equivalent oil yield than other intercropping system of different residual fertility levels. Among the different residual fertility combination of intercrops there was significant different in citronella: linseed, combination but in case of citronella: lentil, significantly highest equivalent yield (127.98) was found in 50% residual fertility level over 75% and at par with 100%. Numerically, the highest equivalent was found in citronella: linseed 75% residual fertility level.

Effect of different treatments on growth and yield attributes of linseed

Growth characters

Data recorded regarding to plant population, plant height at 30 DAS, 60 DAS and at maturity stage and number of branches per plant were recorded, analyzed and presented in table 3. Data presented in table 3 showed that the highest plant population (105.34/m^2), plant height at 30 DAS (20.34 cm) and at maturity (73.42 cm) and number of branches per plant was recorded significantly superior in sole linseed treatments over all other treatments. Data regarding to plant height at 60 DAS showed that there are non significantly differences in plant height at 60 DAS among the treatments. Among the inter cropping treatments with different fertility levels there was to significant difference in growth characters i.e. plant population/m^2, plant height of 30, 60 DAS and at maturity No. of branches/plant but numerically 75% fertility level in C:Li intercropping system found better. The results of present investigation are in close conformity with the findings of Singh and Hussain (2005).

Yield attributing characters

Data presented in table 3 showed that number of capsules/plant, number of seed/capsules, test weight and seed weight/plant were influence significantly differences in the treatments. The highest number of capsule/plant (55.43), number of seed/capsule (7.65), test weigh (7.54) and seed weight/plant (4.43) was recorded linseed sole which was significantly superior over all treatments. Among the intercropping fertility level treatment numerically the highest number of capsule/plant, number of seeds/capsule, test weight and seed weight was found in citronella : linseed 50% fertility level and which was of part with 100% and 75% level.

Yield and Harvest index

According to the data presented in table 3 the highest biological yield (64.77 q/ha), seed yield (19.67 q/ha), and harvest index (30.36%), was recorded in linseed sole which was significantly superior over all other treatments. Among the difference intercropping combination significantly highest biological yield (62.23 q/ha) and straw yield (46.13 q/ha) was found in 100% residual fertility level of intercropping but the highest grain yield was obtained in 50% of fertility level which was numerical at par with 100 and 75% of residual fertility level. Significantly lowest straw yield was found in 50% of residual effect of fertility level over all other treatments.

Effect of different treatments on growth and yield attributes of lentil

Growth characters

Data presented in table 4 showed that the highest plant population (113.50/m^2), plant height at maturity (45.60 cm), and number of branches/plant (20.10) was recorded in Lentil sole which was significantly superior over all other treatments. The finding of Renu Dhar Basu et al. (2007) is in agreement with the present investigation. But in intercropping treatment of residual effects the highest plant population (110.72 m^2) was found in C:L (75%) residual fertility level followed by 100% and 50% residual fertility treatments. There was no significant different. In plant height characters recorded at 30DAS, significantly lowest in 50% residual fertility level but at 60DAS it is highest. There was significantly difference regarding number of branches/plant recorded at 100%, 75% and 50% residual fertility levels. Thus, the growth behavior of the crop performed in a similar way for development activities of plants was reflected in yield attributes and yield of lentil. Similar results were also obtained by Munni *et al.* (1998).

Yield attributing characters

Data presented in table 4 showed that there non-significant differences in number of grains/pod among the treatments. Numerically the highest number of grain/pod was recorded in lentil sole (2.30).

The number of pods/plant, weight of pods/plant and test weight have been recorded significantly highest in sole treatment. Next to sole treatment, the highest number of pods/plant was recorded in 75% residual fertility of intercropping (89.50) follow by 50% (88.70) and 75% (88.25), weight of pods/plant (3.40) and test weight (22.30) was recorded highest in 50% of residual fertility dose of intercropping.

Yield and harvest index

Data in table 4 regarding biological yield, grain yield and straw yield significant difference over other treatments. The highest biological yield (50.25q/ha), grain yield (17.28q/ha) and straw yield (32.35q/ha) were recorded in lentil sole which were significantly superior over all treatments. Next to sole crop and among the intercrop treatments the highest biological yield (27.20 q/ha), grain yield (9.15 q/ha), and straw yield (17.35 q/ha), was recorded in 50% residual fertility combination of intercrops which was significantly superior over 75% residual fertility combination followed by 100% residual fertility level citronella + lentil combination. The lowest biological yield (24.35 q/ha), grain yield (8.20 q/ha), and straw yield (14.45 q/ha), were recorded

Table 1. Effect of different treatments on growth characters and yield attributes of citronella:

Treatments	Leaf length at 8th cutting (cm)	Number of tiller at 8th cutting	Herbage yield of 8th cutting (q/ha)	Oil yield of 8th cutting (Lit/ha)
Citronella sole	72.45	95.34	196.30	165.36
C:Li (100%)	67.63	92.45	103.63	86.54
C:Li (75%)	68.30	91.80	102.62	86.50
C:Li (50%)	67.70	92.70	103.65	85.53
C:L (100%)	67.25	92.30	102.58	84.54
C:L (75%)	68.25	91.75	102.67	85.64
C:L (50%)	67.65	92.65	103.62	84.64

S.E. (d)	0.7621	0.6386	3.2179	0.8431
CD (P = 0.05)	1.6018	1.3425	6.7613	2.2946

Table 2. Effect of Cropping system on Citronella equivalent oil yield (kg/ha)

Cropping system	Citronella	Linseed	Lentil	C:Li (100%)	C:Li (75%)	C:Li (50%)	C:L(100%)	C:L (75%)	C:L(50%)	CD	SE (d)
Equivalent yield	165.36	82.82	81.85	154.32	154.50	154.35	127.50	124.48	127.98	**1.642**	**0.791**

Table 3. Effect of different treatments on growth and yield attributes of linseed:

Treatments	**Plant population /m^2**	**Plant height at 30 DAS**	**Plant height at 60 DAS**	**Plant height at maturity (cm)**	**Number of branches per plant**	**Number of capsule/plant**	**Number of seed /capsule**	**Test weight (g)**	**Seed weight/ plant**	**Biological yield (q/ha)**	**Seed yield (q/ha)**	**Straw yield (q/ha)**	**Harvest index (%)**
Linseed sole	105.34	20.34	50.48	73.42	35.83	55.43	7.65	7.54	4.43	64.77	19.67	45.10	30.36
C:Li (100%)	102.21	18.64	48.32	70.35	33.24	51.48	7.20	6.80	3.80	62.23	16.10	46.13	25.86
C:Li (75%)	102.35	19.42	48.80	70.26	34.65	52.41	6.82	7.05	3.75	61.60	16.15	45.45	26.21
C:Li (50%)	101.72	19.65	48.05	70.45	32.70	52.70	7.35	7.25	4.10	60.33	16.35	43.98	27.09
S.E (d)	0.8563	0.3973	0.8621	0.5821	0.2792	0.2872	0.1064	0.0316	0.0224	0.0347	0.0316	0.0387	0.0528
CD (P =0.05)	1.9358	0.8750	N.S.	1.3160	0.6322	0.7234	0.2060	0.0651	0.0376	0.0471	0.0634	0.0881	0.0577

Table 3. Effect of different treatments on growth and yield attributes of linseed:

Treatments	**Plant population /m^2**	**Plant height at 30 DAS**	**Plant height at 60 DAS**	**Plant height at maturity (cm)**	**Number of branches per plant**	**Number of capsule/plant**	**Number of seed /capsule**	**Test weight (g)**	**Seed weight/ plant**	**Biological yield (q/ha)**	**Seed yield (q/ha)**	**Straw yield (q/ha)**	**Harvest index (%)**
Linseed sole	105.34	20.34	50.48	73.42	35.83	55.43	7.65	7.54	4.43	64.77	19.67	45.10	30.36
C:Li (100%)	102.21	18.64	48.32	70.35	33.24	51.48	7.20	6.80	3.80	62.23	16.10	46.13	25.86
C:Li (75%)	102.35	19.42	48.80	70.26	34.65	52.41	6.82	7.05	3.75	61.60	16.15	45.45	26.21
C:Li (50%)	101.72	19.65	48.05	70.45	32.70	52.70	7.35	7.25	4.10	60.33	16.35	43.98	27.09
S.E (d)	0.8563	0.3973	0.8621	0.5821	0.2792	0.2872	0.1064	0.0316	0.0224	0.0347	0.0316	0.0387	0.0528
CD (P =0.05)	1.9358	0.8750	N.S.	1.3160	0.6322	0.7234	0.2060	0.0651	0.0376	0.0471	0.0634	0.0881	0.0577

Table 4. Effect of different treatments on growth and yield attributes of lentil

Treatments	Plant population /m^2	Plant height at 30 DAS	Plant height at 60 DAS	Plant height at maturity (cm)	Number of branches per plant	Number of pod/plant	Number of grain /pod	weight of pods/plant (g)	Test weight (g)	Biological yield (q/ha)	Grain yield (q/ha)	Straw yield (q/ha)	Harvest index (%)
Lentil sole	113.50	10.50	20.50	45.60	20.10	90.50	2.30	3.50	22.80	50.25	17.28	32.35	33.85
C:L (100%)	109.50	9.20	19.72	40.65	18.56	88.25	2.15	3.30	22.25	26.65	9.07	16.32	35.30
C:L (75%)	110.72	9.80	19.45	41.73	18.70	89.50	2.05	3.25	22.28	24.35	8.20	14.45	36.45
C:L (50%)	109.42	8.90	19.80	40.90	18.70	88.70	2.25	3.40	22.30	27.20	9.15	17.35	34.80
S.E (d)	0.0592	0.0707	0.0866	0.7919	0.4576	0.4695	0.0810	0.0632	0.0774	0.8759	0.4271	0.8794	0.2828
CD (P =0.05)	0.1332	0.1627	0.1973	1.1121	1.0343	1.0613	N.S.	0.1395	0.1785	1.9803	0.9655	1.9881	0.6388

LER:

LER reflects the extra advantage of intercropping system over sole cropping system. LER was more than sole crops which showed and advantage of intercropping over sole system in terms of the use of environment resources for plant growth and development. LER values in citronella + linseed (75%) and citronella +linseed (100%) intercropping system was 1.34. The results indicated that 0.34% more area would required by a sole cropping system to recover the yield of intercropping system, citronella + linseed (50%) intercropping system recorded the maximum equivalent yield than sole cropping. It might be due to significant increases in grain yield of linseed in aforesaid treatment over sole which resulted in higher citronella equivalent yield followed by citronella : lentil (75%).

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RESEARCH ARTICLE

STUDIES ON THE EFFECT OF WEATHER CONDITIONS ON INFESTATION OF MAIZE STEM BORER *CHILO PARTELLUS* SWINEHOE, AND SORGHUM SHOOT FLY, *ATHERIGONA SOCCATA* RONDANI, ON MAIZE, *ZEA MAYS* L.

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Abstract: The present investigation was conducted at Students' Instructional Farm (SIF) of Chandra Shekhar Azad University of Agriculture and Technology Kanpur, (U.P.) during *Kharif*- 2016 and 2017 to study the infestation of maize stem borer and sorghum shoot fly in relation with biotic factors viz. maximum and minimum temperature, relative humidity and rainfall. The incidence of maize stem borer increased gradually and reached to peak with 28.10 per cent and 27.80 per cent infestation in 53 days (33rd SMW) and 53 days (33rd SMW) in *Kharif* season during both the year i.e. 2016 and 2017, respectively. Similarity the formation of dead heart of sorghum shoot fly increased gradually and reached to peak in tune of 22.60 per cent and 20.80 per cent in 34 days (30th SMW) and 34 days (30th SMW) during 2016 and 2017, respectively. The maximum pest population was trapped during 3rd week of August (33rd SMW) in both years, when the maximum temperature i.e. 31.70 ºC and 34.30 ºC and minimum i.e. 25.50 ºC and 26.10 ºC, respectively, were recorded and relative humidity' of 84.60 per cent and 77.00 per cent, respectively, and total rainfall i.e. 33.10 and 27.80 mm. respectively, were observed. The maize stem borer and sorghum shoot fly incidence in the form of dead heart was correlated with the meteorological parameters of corresponding period of observations.

Keywords: Maize stem borer *Chilo partellus* Swinehoe, Sorghum shoot fly, Seasonal incidence, *Zea mays* L.

INTRODUCTION

Maize (*Zea mays* L.), is an important cereal crop widely grown for food and as livestock feed. Maize ranks with wheat and rice as one of the world's chief grain crops. Globally, India stands 5th rank in acreage and 8th rank in production of maize. It is cultivated in 9.26 million hectares with a production of 21.81 million tones having productivity of 25.10 quintals ha^{-1} and contributes about 3% towards total world food production. In India, current consumption pattern of maize is poultry, pig, fish feed 52%, human consumption 24%, cattle feed and starch 11% and seed and brewery industry 1% (IIMR, New Delhi, 2016-17). More than 150 insect species damage the crop from sowing to harvest. The continuous cropping of maize during the '*Kharif*', '*rabi*' and spring seasons has led to a change in the insect-pest complex with the occurrence of sorghum shoot fly, *Atherigona soccata* Rondani, in spring maize stem borer, *Chilo partellus* Swinhoe, in *Kharif* and pink stem borer ,*Sesamia inference* Walker, in rabi sown maize as noxious insect pests. When infestation is severe, there is a physiological disruption of plant growth, hence tasselling, silking and grain formation are severely affected (Addo Bediako and Thanguane, 2012). Among the various insect pests, maize stem borer, *C. partellus* is the most dominant contributing 90-95 per cent of the total damage in *Kharif* season (Jalali and Singh, 2002). Maize is most vulnerable to *C. partellus* (Lepidoptera: Crambidae) which causes severe losses to it (Songa *et al*, 2001) In controlling harmful insects the methods rely on a sound knowledge of insect ecology & physiology. Stem borers initial damage is caused by feeding on the leaf tissues, followed by tunneling and feeding within the stem and sometimes the maize cobs. After hatching, the first instar larvae move into the leaf whorls where they feed and develop on the bases of the leaves, causing lesions. The late third or early fourth instars bore into the stem, feeding on tissues and making tunnels.

It is common to see removing of maize crop due to heavy infestation of shoot fly. Shoot fly is one of the most important and destructive pest causing damage at seedling stage. In India, about five per cent of the loss has been attributed to sorghum shoot fly (Jotwani 1983). Stem borer infestation starts about 20 days after seedling emergence, and dead hearts appear on 30-40-days-old crop. A female can lays up to 500 eggs in batches of 10-80 near the midrib on the under surface of the leaves. Eggs hatch in 4-5 days. The larvae move to the leaf whorl and feed on tender leaves resulting in leaf-scarification and shoot holes. Third instars larvae move to the base of the plant and bore into the shoot. Damage to the growing point results in the production of a typical dead hearts. In mature plants, the larvae make tunnel inside the stem. The larval development is completed in 19-27 days. Pupation takes place inside the stem and the adults emerge in 7-10 days. Sorghum shoot fly (*A. soccata*) is a key pest of sorghum in Asia; shoot fly females lay cigar-shaped eggs singly on the lower surface of the leaf, at 1-7 leaves stage. Eggs hatch in 1-2 days. The larva cuts the growing point,

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resulting in wilting and drying of the central leaf, known as "dead heart". The dead heart can be pulled out easily, and it produces a bad smell. Normally, the damage occurs 1-4 weeks after seedling emergence. The damaged plants produce side tillers that also may be attacked. Larval development is completed in 8-10 days and pupation takes place mostly in the soil. The pupal period lasts for 8 days. The shoot fly populations exhibit considerable variation, normally very low from April to June, tend to increase in July and reaches peak in August. From September onwards the population gradually declines and with slight increase there will be a small peak in October and thereafter remains at a moderate level till March (Balikai, 2000). It's activity is influenced by extreme temperatures (above 35ºC and below 18ºC), and also by continuous rains. Balikai and Venkatesh 2001 reported that, rainfall received at one week after emergence and higher day temperature at two weeks after seedling emergence reduced shoot fly infestation, whereas lower afternoon relative humidity at 4 weeks after emergence increased shoot fly infestation. Karibasavaraja *et al*. 2005. Also reported that, the pest was active throughout the study period of four months starting from 27th to 44th standard week. However, more work has not been done on management of serious insect-pests under agro-climatic conditions of central Uttar Pradesh.

MATERIALS AND METHODS

A plot size of 6x4 m^2 with Azad Uttam, a promising variety was raised and maintained without insecticide application to study the occurrence of major insect pests on maize in relation to a biotic factors *viz*., maximum temperature, minimum temperature, relative humidity (morning and evening) and rainfall were recorded. The rainy maize crop was sown on 20^{th} June of both year i.e. 20016 and 2017 following standard agronomical practices. The incidence of stem borer and Sorghum Shoot fly were recorded soon after noticing the initial dead shoots caused by this pest were counted in each entry from the first appearance, and continued up to the maturity of the crop at weekly intervals throughout the growing season. The occurrence of maize stem borer, *Chilo partellus* Swinehoe, was observed by 10 randomly selected plants at ten different locations of the plot. Then the stems were count the number of larvae of *Chilo partellus* Swinehoe at seven days interval starting from seven days after germination till harvest of the crop. The occurrence of sorghum shoot fly, *Atherigona soccata* Rondani, was observed by 5 randomly selected plants at five different locations of the plot. Then the dead heart was count the number of larvae of *Atherigona soccata* Rondani, at seven days interval starting from seven days after germination till harvest of the crop.

RESULTS AND DISCUSSION

A: Maize stem borer (*Chilo partellus* Swinehoe)

The data presented in table (01 and 02) revealed that the population of *C. partellus* gradually increased and reached to peak on 33^{rd} SMW i.e. 53 days after sowing in both years i.e. 2016 and 2017 with a formation of mean number of dead hearts i.e. 28.10 and 27.80 per cent, respectively. The maximum and minimum temperature prevailed during both years were 31.70 ^{0}C, 34.30 ^{0}C, respectively, and 25.50 ^{0}C, 26.10 ^{0}C, respectively, and the average relative humidity was recorded in terms of 84.60 per cent and 77 per cent, respectively, while total rainfall was observed 33.10 and 1.00 mm

B: Sorghum shoot fly (*Atherigona soccata* Rondani)

It is quite clear from the data presented in table (03 and 04) that the pest *A. soccata* population increased gradually and reached its peck on 30^{th} SMW i.e. 34 days after sowing with a formation of mean number of dead hearts i.e. 21.60 and 20.80 per cent in both the years, respectively. The maximum and minimum temperature prevailed during the period was 32.60 ^{0}C, 31.30 ^{0}C, respectively, and 25.90 ^{0}C, 25.40 ^{0}C, respectively. The average relative humidity was recorded in terms of 82.90 per cent and 83.00 per cent, respectively, while total rainfall was observed 29.90 and 42.40 mm., respectively, was noticed during these standard weeks continuously.

This study was in agreement with the observations made by Jalali and Singh 2002, who observed that the occurrence of *C. partellus* started during the third week of December i.e., 28 days after sowing (three weeks after crop emergence). These findings` also confirmed the work of Timaru *et al*., 2012, as most suitable condition for *Chilo partellus* Swinehoe development was 26 to 30 ºC temperature. Regarding the maize growing season, mean of the weeks revealed that borer damage was comparatively less i.e. 22.50 per cent at 21.1 ºC during winter seeded maize plants than spring season (47.08% at 28.78 ºC) and rainy season (47.03% at 29.2 ºC). The results are also in close approximation with, Thakur *et al*., 2013. Who reported that the insect's injury was approximately in the same trend in both the years proportional to prevailing temperature. Percentage stem borer infestation was gradually increased toward the progress of weeks and more or less remained constant from 10 to 42 weeks and further started declining gradually. Thus, the temperature was pronounced resulting in higher percentage of infestation.

Table 1. Seasonal incidence of maize stem borer on maize, *Kharif* 2016

S.W.M.	Date of observation	Temperature (ºC)		Relative humidity (%)	Rainfall (mm)	Mean of dead heart (%)
		Max.	Min.			
29	16-Jul 22	31.70	26.10	84.60	30.20	0.00
30	23-29	32.60	25.90	82.90	29.90	4.20
31	30-Aug 5	32.10	25.60	82.60	70.70	7.20
32	6-12	32.30	26.20	81.30	67.90	13.20
33	13-19	31.70	25.50	84.60	33.10	28.10
34	20-26	32.70	25.20	77.40	5.60	20.10
35	27-Sep 2	34.40	26.50	77.90	8.40	12.20
36	3-9	33.80	25.90	73.00	00.00	10.60
37	10-16	32.80	25.00	77.90	7.00	8.70
38	17-23	32.60	25.30	82.90	7.80	6.10
39	24-30	32.60	24.10	79.20	5.70	3.60
40	1-Oct 7	34.90	24.80	71.70	20.00	1.70

Table 2. Seasonal incidence of maize stem borer on maize, *Kharif* 2017

S.W.M.	Date of observation	Temperature (ºC)		Relative humidity (%)	Rainfall (mm)	Mean dead heart (%)
		Max.	Min.			
29	16-Jul 22	33.70	25.80	80.00	16.00	0.00
30	23-29	31.30	25.40	83.00	42.40	2.80
31	30-Aug 5	33.20	26.30	78.00	5.30	8.20
32	6-12	33.10	25.80	84.50	112.60	12.90
33	13-19	34.30	26.10	77.00	1.00	27.80
34	20-26	32.90	25.50	84.00	89.20	21.20
35	27-Sep 2	33.30	25.20	82.50	2.20	11.40
36	3-9	35.10	25.30	77.00	3.60	9.50
37	10-16	36.20	25.70	72.20	0.00	7.60
38	17-23	33.70	25.30	85.00	34.50	6.10
39	24-30	34.20	23.30	75.00	0.20	2.10
40	1-Oct 7	35.40	22.70	69.00	0.00	1.00

Table 3. Seasonal incidences of Sorghum shoot fly on maize, *Kharif* 2016

S.W.M.	Date of observation	Temperature (ºC)		Relative humidity (%)	Rainfall (mm)	Mean dead heart (%)
		Max.	Min.			
25	18- Jun 24	32.60	25.20	78.40	97.10	0.00
26	25-Jul 1	36.90	26.50	66.40	11.00	0.00
27	2-8	31.60	25.10	86.90	126.10	4.80
28	9-15	32.80	26.10	85.40	77.60	7.20
29	16-22	31.70	26.10	84.60	30.20	9.60
30	23-29	32.60	25.90	82.90	29.90	21.60
31	30-Aug 5	32.10	25.60	82.60	70.70	10.40
32	6-12	32.30	26.20	81.30	67.90	5.60
33	13-19	31.70	25.50	84.60	33.10	0.00
34	20-26	32.60	25.20	77.40	5.60	0.00
35	27-Sep 2	34.40	26.20	77.90	8.40	0.00
36	3-9	33.80	25.90	72.90	0.00	0.00

Table 4. Seasonal incidence of Sorghum shoots fly on maize, *Kharif* 2017

S.W.M.	Date of observation	Temperature (ºC)		Relative humidity (%)	Rainfall (mm)	Mean dead heart (%)
		Max.	Min.			
25	18-24 Jun	36.80	26.00	66.00	5.90	0.00
26	25-Jul 1	37.00	28.50	66.00	42.80	0.00
27	2-8	29.40	24.50	90.00	240.80	5.60
28	9-15	30.80	25.80	87.50	19.50	6.40
29	16-22	33.70	25.80	80.00	16.00	10.40
30	23-29	31.30	25.40	83.00	42.40	20.80
31	30-Aug 5	33.20	26.30	78.00	5.30	11.20
32	6-12	33.10	25.80	84.50	112.60	4.00
33	13-19	34.30	26.10	77.00	1.00	0.00
34	20-26	32.90	25.50	84.00	89.10	0.00
35	27-Sep 2	33.33	25.52	82.50	2.20	0.00
36	3-9	35.10	25.30	77.00	3.60	0.00

Correlations of maize stem borer ad sorghum shoot fly and regression of pest population with weather parameters.

The interactions between the pest population of *C. partellus and* weather parameters during rainy season 2016 and 2017 revealed non significant correlation with maximum temperature, minimum temperature, relative humidity and rainfall. The interaction between the pest population of *C. partellus* and weather parameters showed non significant negative correlation with maximum temperature (r= - 0.188 and r= - 0.056) with maize stem borer infestation. However, non significant positive correlation was observed with other meteorological parameters viz. minimum temperature (r= 0.161), total rainfall (r= 0.280 and 0. 277) and average relative humidity (r= 0.137 and 0. 250), respectively, and significant positive correlation with minimum temperature (r= 0.472*). The interactions between maize stem borer larvae population and prevailing weather parameters as obtained in the present investigation are in accordance with the findings of (Patel *et al*., 2016).

The interactions between the pest population of *A. soccata* and weather parameters during rainy season 2016 and 2017 showed non significant negative correlation with maximum temperature (r= - 0.348 and 0.516) with sorghum shoot fly infestation. However, non significant positive correlation was observed with other meteorological parameters viz. minimum temperatures (r= 0.133 and - 0.212), total rainfall (r= 0.157 and 0.040) and average relative humidity (r= 0.480* and 0.430) have positive significant relation with the pest population of shoot fly.

Table 5. Correlation coefficient and regression equation between biotic factors and incidence of stem bore (Y_1), shoot fly (Y_2) on maize

Weather variable	Stem bore		Shoot fly	
	2016	2017	2016	2017
Max. Temperature (^{0}C) (X_1)	-0.1886	-0.056	-0.348	-0.516*
	NS	NS	NS	
Min. Temperature (^{0}C) (X_2)	0.161	0.472*	0.133	-0.212
	NS		NS	NS
Av. Relative humidity (%) (X_3)	0.137	0.250	0.480*	0.340
	NS	NS		NS
Total Rainfall (mm) (X_4)	0.280	0.277	0.157	0.040
	NS	NS	NS	NS

** Significant 0.01 levels. * Significant at 0.05 levels

Year	Multiple regression equation	(R^2)
Maize stem borer		
2016	$\mathbf{Y_1=}$ 1.02 + 1.12 (X_1) + 0.05 (X_2) + 0.07 (X_3) -0.22 (X_4)	**0.988**

2017	$\mathbf{Y_2=}$ -127.14 + 0.63 (X_1) – 0.45 (X_2) +3.46 X_3) + 1.51 (X_4)	**0.538**

Sorghum shoot fly

2016	$\mathbf{Y_1=}$-171.92- 0.01 (X_1) + 0.60 (X_2) + 5.73 (X_3) -0.57 (X_4)	**0.593**
2017	$\mathbf{Y_2=}$266.53 - 0.04 (X_1) – 1.05 (X_2) + 0. 39 (X_3) – 5.57(X_4)	**0.743**

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RESEARCH ARTICLE

INFLUENCE OF DIFFERENT PRE-TREATMENTS METHODS ON SEED GERMINATION AND SEEDLING GROWTH PERFORMANCE OF GOLDEN SHOWER TREE (*CASSIA FISTULA* L.)

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Abstract: The present study was conducted to find out the effect of different pre –treatments method on seed germination and seedling growth performance of Golden Shower Tree *(Cassia fistula* L.*)* at Forest nursery and Research Centre, SHUATS, Allahabad, India, during the month of June – September 2018. The seeds were pre-treated with different methods such T_0- Control, T_1- hot water 20 min + soaking in cold water 12 hrs, T_2- cold water 24 hrs, T_3- IAA 200 ppm 12 hrs, T_4- IBA 200 ppm 12 hrs, and T_5- Conc H_2SO_4- 2 Min+ 16 Hrs soaking in cold water and sown in poly bags filled with FYM 2:1:1 at Completely Randomized Design. The results indicated the maximum Germination percentage (78.89), Number of leaves (6.49) at 30 DAS, 7.29 AT 60 DAS, 9.21 at 90 DAS, shoot height (25.25 cm) at 90 DAS, root length (17.77cm), fresh shoot weight (7.27g), dry shoot weight (3.82g), fresh root weight (4.38g), dry root weight (2.78g) and vigour index (121.89) recorded in T_5. However T_0 Control had no germination. Therefore, the results showed that the best pre-treatment method T_5 was more effective in germination and significantly improved the growth parameters as well as the quality seedling of *Cassia fistula* L.

Keywords: *Cassia fistula,* Pre-treatment, Seed germination, Seedling growth

INTRODUCTION

India is blessed with with a storehouse of natural flora and fauna. it's calculable that there that there are more than 45,000 plant species in India. It is estimated that over 6000 plants in India are in use in traditional, folk and herbal medicine (Danish *et al.*, 2011). Among these 866 species are considered to be the potential medicinal plants in Indian trade. India officially recognizes over 3000 plants for their medicinal value. World health Organization reported that traditional medical practitioners treat about 85 per cent of patients in India (WHO survey, 1993), which shows the significant valuable relation between local tribal people with medicinal plants. The WHO estimated that 80 per cent of the population of developing countries depends on traditional medicines. Among which India's contribution is 15-20 per cent and in India about 2000 drugs used are of the plant. The pod of *C. fistula* has been used as a laxative drug in Thai ancient drugs for a protracted time.

The degree of laxative potency is dependent on the content of anthraquinone glycosoides. The plant contains anthraquinone glycosoides as both glycones and glycosoides has been used as an alternate supply of stuff for numerous flavouring laxative medication preparations (Sakulpanich and Gritsanapan, 2009). *C. fistula* leaf appear to be potential sources of anti-obesity and hypolipidemic compounds which could be developed as phytomedicines or drugs (Christine *et al.*, 2011). Leaf and Root Extract of *Cassia fistula* may play a helpful role within the in the management of bacterial infections (Awal *et al.,* 2010). The tree is distributed naturally throughout the tropical and subtropical regions of India.

Golden Shower Tree *(Cassia fistula L.)* is a member of the family *Caesalpiniaceae* known for its characteristic bunches of beautiful yellow flowers and grows throughout India. The tree is a native plant of India, naturalized in Africa, West Indies and South America. . it's earned importance as a decorative and avenue plant (Arora, 1988). This species has been introduced in different plantation programs like agro-forestry, community forestry, social forestry, village and farm forestry in different parts of Bangladesh (Khan *et al.,* 2006). It is a fast-growing tree which reaches 30 to 40 feet in height.

The well-spaced branches are clothed with pinnately compound leaves, with leaflets up to eight inches long and 2.5 inches wide. These leaves will drop from the tree for a short period of time and are quickly replaced by new leaves. In summer, Golden-Shower is decorated with thick clusters of showy yellow blooms which cover the slightly drooping branches. The blooms are followed by the production of two-foot-long, dark brown, cylindrical pods which persist on the tree (Gilman and Watson, 1993). Its leaves, stem, bark and pods having antibacterial and antifungal activity (Duraipandiyan and Ignacimuthu, 2007).

The pods of *C. fistula* L. are straight cylindrical pods, 20-60 cm long and 1.5-2 cm in diameter. The pod is dark green when young, turning dark brown to black when mature. The ripe pod contains dark color sweetish pulp and numerous yellowish-brown seeds. The pods should be collected when ripe and carefully dried. The best pods are those which do not rattle

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when shaken. These possess the most pulp. The pulp of ripe pods and mature leaves are known to have laxative drug property (Gritsanapan, 2010). The leaf extract *C. fistula* has potent mosquito larvicidal property (Mehdi *et al.,* 2011).

The importance of seed treatment is that it helps to resolve seed dormancy. Seed treatment chemicals also have been shown to increase germination rates, vigor and root development. The use of this service is important to ensure the seed is not undertreated and risking the loss of protection, or over-treated, which wastes money and affects seed health. When you are treating the seed with the essential nutrients, there are a number of advantages that you have. The first one is of course higher germination of plants (Rout *et al.,* 2017; Rout *et al.,* 2016; Dilip *et al.,* 2017; Singh *et al.,* 2016).. Keeping in the view above mentioned constraints, the topic entitled "Effect and variations of different Pre-treatments on seed germination of Golden Shower Tree (*Cassia fistula* L.).

MATERIALS AND METHODS

The experimental studies entitled were carried out in the Forest Nursery and Research Centre, College of Forestry, Sam Higginbottom Institute of Agricultural, Technology and Sciences, Pryagraj 211007 (U.P) during the period of June 2018- September 2018. The experimental treatments consisted of T_0- Control, T_1- hot water 20 min + soaking in cold water 12 hrs, T_2- cold water 24 hrs, T_3- IAA 200 ppm 12 hrs, T_4- IBA 200 ppm 12 hrs, and T_5- Conc. H_2SO_4- 2 Min+ 16 Hrs soaking in cold water, and 4 replications for each treatment. The experiment was conducted at the Forest Nursery and Research Centre, College of Forestry, SHUATS, Pryagraj 211007 Uttar Pradesh which is situated 6kms away from Allahabad city on the right bank of Yamuna river, the experimental site is located in the sub-tropical region with 25 57' N latitude, 81 57' E longitude and 98 meters above the mean sea level. All the necessary facility including labor was readily available in the College. Pryagraj is very close to the reference point for IST (Indian Standard Time), it is 2.6 minutes behind IST. The climate in this part of the country has been classified as semi-arid with both the extent of temperature during the winter and summer. From December to January, the temperature may drop down to as low as 2^o C, while it may exceed 47^o C during May-June. Frost during winter and hot air during summer are common occurrences. The average annual rainfall is about 102 cm with maximum concentration during July to September and with occasional showers during the winter season (Patra *et al.,* 2016). A total of 180 seeds were used with 30 seeds allocated for each treatment. The seeds were subjected to best pre sowing treatment (including control) after which they were germinated in poly bags. Then the pre-treated seeds were sown in poly bags with a mixture of Soil, Sand and FYM (2:1:1) in a completely randomized block design with the treatments. One seed was sown in each poly bag. The seeds were then be watered daily to provide moisture that helped in the germination of the seeds. The poly bags were arranged in accordance with the treatment. The germination was recorded daily and seedling growth from each treatment was recorded accordingly at an interval of 30 days each. Data were recorded for the No of seed germinated, number of leaves/plant at 30, 60, 90 DAS, shoot height at 30, 60 and 90 DAS, root length (cm), fresh weight of shoot (g), fresh weight of root (g), dry weight of shoot (g), dry weight of root (g) and vigour indexed were calculated (Abdul and Anderson, 1973). The data obtained from the experiment was statistically analyzed by an appropriate procedure to completely randomized design (CRD) as described by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Seed germination percentage (%)

The result of the present experiment indicates that germination started earlier in T_5, T_4, T_3, $T_{1,}$ T_2 However T_0 Control did not have any germination. In all treatments, germination completed within 10-20 days after sowing the seeds in the polybags. The data for germination percentage recorded at successive stages of Golden shower tree is presented in table 1(a). Results revealed highly significant differences ($p< 0.05$) between different pre-treatment methods on germination percentage. Data appended in table 1 (a) revealed that the germination percentage showed significant difference with all the treatments. The average germination percentage was observed maximum in T_5 (78.89%). The minimum was seen at T_0 at (0.00%). The second best treatment was T_4 (72.23%), T_3 (68.89%), T_2 (65.56%), T_1 (62.23%). The positive effects of H_2SO_4 on germination percentage of *Cassia fistula* were also found by Zarchini *et al.,* (2011) who reported that H_2SO_4 pre treatment resulted in higher seed germinations.

Number of leaves

Persual of the data appended in table 1(a) revealed that the number of leaves was significantly influenced by different pre-treatment methods at a different stage of the growth of the seedlings.

Data appended in table 1(a) revealed that after 30 DAS, it was found that the number of leaves show significant differences among all the treatments. However, the average number of leaves after 30 days was observed maximum in T_5 (6.49) followed by T_3 (6.47) and the minimum was recorded in T_0.

It was revealed from table 1(a) that after 60 DAS, it was found that the number of leaves show significant differences among all the treatments. However the average number of leaves after 60 days was observed maximum in T_5 (7.29) followed by T_3 (7.27) and the minimum in $T_{0.}$

After 90 days it was found that the number of leaves shows significant difference among all treatments. However the average number of leaves after 90 days observed maximum in T_5 (9.21) followed by T_3 (8.17) and the minimum in T_0. Supporting results were obtained by Mabundza *et al.*, (2010) in *Tamaraindus indica* L. with 95% H_2SO_4 for 5 Min seed pre treatment enhanced the seed germination and the number of leaves.

Shoot height (cm)

In general the plant height increased with age of the plant. However, margin of increase was highest after the 60 days period of sowing irrespective treatments.

Perusal to the data appended in table 1(a) revealed that after 30 DAS. It was found that the shoot height shows significant differences among all treatments. The average plant height was observed maximum in T_5 (16.93) followed by T_4 (13.83) and the minimum in $T_{0.}$

From the table 1(a) revealed that after 60 DAS, it was found that the shoot height shows significant differences among all the treatments. However the average shoot height after 60 days was observed maximum in T_5 (23.43) followed by T_3 (19.83) and the minimum in $T_{0.}$

After 90 days it was found that the shoot height shows significant difference among all treatments. However the average shoot height after 90 days observed maximum in T_5 (25.23) followed by T_3 (20.33) and the minimum in $T_{0.}$ Similar results were also obtained by Agbogid *et al.*, (2007) who demonstrated that acid pre treatment of *D. edulis* has the highly significant effect of improving seed viability and enhances seedling emergence and growth.

Root length (cm)

Given on the data in table 1(b) revealed that the root length of the seedlings was significantly influenced by different pre-treatment methods at different stages of the growth of seedlings.

Data appended in table 1(b) revealed that after 90 DAS, it was found that the root length of the seedlings showed a significant difference among all the treatments. However the average root length of the seedlings after 90 days was observed maximum in T_5 (17.77) followed by T_4 (15.37) and the minimum was recorded in T_0. The results are in agreements with those obtained by Anim Kuapong and Teklehaimanot (2001) who found that root length significantly affected by treatment and length of root was recorded in seed *Albizia zygia* scarified by H_2SO_4 for 5 Min.

Fresh weight of Shoot (g)

Given data table 1(b) revealed that the fresh weight of shoot was significantly influenced by different pre-treatments methods at different stages of the growing seedlings. Data appended in table 1(b) revealed that after 90 DAS, it was found that the fresh shoot weight of the seedlings showed significant differences among all the treatments. However the average fresh weight of shoot of the seedlings after 90 days was observed maximum in $T_{0.}$

Dry weight of shoot (g)

Given data in appended in table 1(b) revealed that dry weight of shoot of the seedlings was significantly influenced by different pre-treatment methods at different stages of the growth of seedlings. Data appended in table 1(b) revealed that after 90 DAS. It was found that the dry weight of shoot of the seedlings showed significant differences with all the treatments.

However the average dry weight of shoot of the seedlings after 90 days was observed maximum in T_5 (3.82) followed by T_4 3.06 and the minimum recorded in $T_{0.}$

Fresh weight of root (g)

Persual of the data appended in table 1(b) revealed fresh root weight of seedlings was significantly influenced by different pre-treatment methods at different stages of the growth of seedlings. Data appended in the table 1(b) revealed that after 90 DAS. It was found that the fresh weight of root of the seedlings showed significant differences among all the treatments. However the average root weight of seedlings after 90 days was observed maximum in T_5 (4.38) followed by T_4 (4.08) and the minimum recorded at $T_{0.}$

Dry weight of root (g)

Given data in table 1(b) revealed that dry weight of root the seedlings was significantly influenced by different pre-treatment methods at different stages of the growth of seedlings. Data appended in table 1(b) revealed that after 90 DAS, it was found that the dry weight of root of the seedlings showed significant difference with all the treatments. However that average dry root weight of seedlings after 90 days was observed maximum in T_5 (2.78) followed by T_4 (2.36) and minimum in $T_{0.}$ Gupta *et al.*, (2001) showed that different treatment H_2SO_4 treated for 5 min was the most effective in breaking the dormancy which was imposed by the seed coat in *Abutilon indicum.*

Vigour Index (VI)

Given in table 1(b) revealed that vigour index of the seedlings was significantly influenced by different pre-treatments methods at different stages of the growth of seedlings.

Data appended in table 1(b) revealed that after 90 DAS, it was found that vigour index of the seedlings showed significant differences among all treatments. However the average vigour index of seedling after 90 days was observed maximum.

Table 1. Effect of various pre-treatment methods on seedling growth of Golden Shower Tree (*Cassia Fistula L.*)

S. No.	Treatments	Germination (%) average	No. of leaves @30 DAS	No. of leaves @ 60 DAS	No. of leaves @ 90 DAS	Shoot height @30 DAS (cm)	Shoot height @ 60 DAS (cm)	Shoot height @ 90 DAS (cm)
1	T_0-Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	T_1- hot water 20 min + soaking in cold water 12 hrs	62.23	6.22	6.88	7.08	12.43	15.03	15.73
3	T_2- cold water 24 hrs	65.56	6.12	7.18	8.00	11.43	16.03	16.73
4	T_3- IAA 200 ppm 12 hrs	68.89	6.47	7.27	8.17	11.53	17.43	18.93
5	T_4- IBA 200 ppm 12 hrs	72.23	4.61	5.81	8.11	13.83	19.83	20.33
6	T_5- Conc. H_2SO_4- 2 Min+ 16 Hrs soaking in cold water	78.89	6.49	7.29	9.21	16.93	23.43	25.23
	C. D. (P = 0.05)	1.86	0.13	0.80	0.74	0.76	1.14	1.52

Table 1. Effect of various pre-treatment methods on seedling growth of Golden Shower Tree (*Cassia Fistula L.*)

S. No.	Treatments	Root length (cm)	Shoot fresh weight average(g)	Shoot dry weight average (g)	Root fresh weight average (g)	Root dry weight average (g)	Seed vigour index
1	T_0-Control	0.00	0.00	0.00	0.00	0.00	0.00
2	T_1- hot water 20 min + soaking in cold water 12 hrs	9.67	3.87	2.27	3.26	2.04	87.63
3	T_2- cold water 24 hrs	14.37	4.97	2.73	3.43	2.17	96.66
4	T_3- IAA 200 ppm 12 hrs	14.07	5.25	2.94	3.96	2.25	101.89
5	T_4- IBA 200 ppm 12 hrs	15.37	5.67	3.06	4.08	2.36	107.93
6	T_5- Conc. H_2SO_4- 2 Min+ 16 Hrs soaking in cold water	17.77	7.27	3.82	4.38	2.78	121.89
	C. D. (P = 0.05)	1.52	0.73	0.37	0.74	0.45	15.17

CONCLUSION

Based on the above results, it is concluded that the seeds which were treated in concentrated H_2SO_4 for 2 minutes + 16 hrs cold water performed significantly better than the other treatments. Beside, seedling growth was found more effective in respect to faster germination, higher germination percentage and dry matter production compared to the other applied pre-treatments. Considering that the seeds of *Cassia fistula L.* have a very hard seed coat and almost impermeable to water or moisture, the acid helps to resolve the seed dormancy and quality seedling production of this ornamental tree species.

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RESEARCH ARTICLE

EFFICACY OF PLANT DERIVED ESSENTIAL OILS AGAINST *SITOPHILUS ORYZAE* (L.) IN STORED WHEAT GRAINS

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Abstract: Certain plant derived essential oils are known as a source of secondary metabolites and used as insecticides to repel insects. As part of an effort aimed at the development of reduced-risk pesticides based on plant essential oils, the toxicity of essential oils was investigated against rice weevil *Sitophilus oryzae* L. under laboratory conditions i.e. 28±2^{0}C temperature, 60±5% relative humidity and a 16:8 light:dark photoperiod in BOD. The treatments were the essential oil from various botanicals i.e. Eucalyptus (*Eucalyptus globules*), Lemongrass (*Cymbopogon citrates*), Citrus *(Citrus maxima*) and their different combinations. Data was recorded for various parameters *viz.* per cent adult mortality, grain damage, weight loss and progeny emergence. Study revealed that the combination of essential oils of Eucalyptus (0.5 %) + Lemon grass (0.5 %) was found to be significantly superior among all the treatments and recorded consistently increased rate of adult mortality 61.67, 78.33 and 96.67 % after 7, 14 and 21 days and progeny emergence 60.28, 56.17 and 54.78, respectively. This treatment also recorded with minimum loss in weight and minimum grain damage after 75 days of insect release. The minimum adult mortality, maximum grain damage and maximum weight loss were recorded in control. The validated information provides ample scope for the use of essential oils against store grain pests.

Keywords: Wheat, *Sitophilus oryzae,* Management, Essential oils

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second most important cereal crop of India next to rice. Wheat is the major source of protein in human foods, having higher protein content than maize, rice and other major cereal grains. Stored products are subjected to sustain considerable quantitative and qualitative losses by more than 600 species of beetle pest and 70 species of moths (Rajendran and Sriranjini 2008). In stored grain, insect damage may account for 10- 40 % of loss worldwide (Matthews 1993) whereas in India it was estimated as 6.5 % of the total storage, Raju (1984). Wheat is infested by various insect pests during storage condition. Among all insects *Sitophilus oryzae* is a major insect of cereal crops in storage Baloch (1992). Grub and adults of *S. oryzae* are internal feeders and cause severe qualitative and quantitative losses to wheat grains, Nalini *et al*., (2007). Plant synthesized natural products are well known to have a range of useful insecticidal properties against insect pests' Arthur (1996). In this regard, the toxicity of different essential oils has been evaluated for their insecticidal properties against different stored grain pests (Shaaya, *et al*., 1991; Sarac *et al.,* 1995; Tunc, *et al*., 2000; and Negahban, *et al*., 2006). The control of rice weevil and other pests of stored products by the use of essential oils is the most widely adopted method, while chemical insecticides have serious drawbacks, such as environmental pollution, insect's resistance, high mammalian toxicity and increasing cost of application. This leads to search for more safe and less expensive alternative chemicals such as plant extracts as alternatives to synthetic insecticides. Over 2000 species of plants are known to possess some insecticidal activities (Klocke 1989). Therefore, the aim of present investigation was to evaluate the toxicity of various botanical essential oil alone or in combinations on biological performance of *S. oryzae*.

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MATERIALS AND METHODS

Preparation of essential oil extraction

The fresh leaves of plants *i.e.* eucalyptus, lemongrass and citrus were collected from the H.R.C., Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut. Collected samples were shadow dried under good ventilation for 48 Hrs and woody stems were separated. Shadow dried leaves were used for oil extraction. The leaves of Eucalyptus, Lemongrass and Citrus were cut into small pieces separately and small pieces of leaves were hydro-distilled in Clevenger apparatus continuously for 6 to 7 Hrs at 60 to 70^{0}C temperature to yield essential oils. The oils were collected in eppendorf tubes separately and stored at 4^{0}C temperature in refrigerator.

Insect culture

Adults of test insects *i.e. S. oryzae* were collected locally from naturally infested stored wheat grains. The culture of *S. oryzae* was maintained at 28±2^{0}C temperature, 60±5% relative humidity and a 16:8 light:dark photoperiod in BOD. The culture was raised by 50 pairs of newly emerged *S. oryzae* adults into 500g of wheat grains in 1 Kg capacity plastic container. After 45 days newly emerged (F_1) adults were collected and used for the experimental purpose. Ten pairs of adult *S. oryzae* were released in each 50g of experimental and control grains kept in 300g plastic container which was covered with a lid. The containers were maintained at 28±2^{0}C temperature, 60±5% relative humidity and a 16:8 light:dark photoperiod in BOD.

Observation and calculation

The assessment parameters comprised of adult mortality number of F_1 progeny produced and progeny reduction in both treatment and control conditions, % grain damage, and % weight loss were investigated during experimentation.

Adult mortality

To collect the adult mortality data the Whatman filter papers no. 1 treated with different testing doses were fixed at bottom of containers and filled with 50g of wheat grains. In control the ethanol treated filter papers were fixed at bottom of containers. Ten pairs freshly emerged adults were released in each container and kept in BOD at 28±2^{0}C temperature, 60±5% relative humidity and a 16:8 light:dark photoperiod in BOD. Each treatment was replicated thrice. The adult mortality was recorded at 7, 14 and 21 days after released. The following formula was used to calculate the % mortality:

$$\text{Adult mortality (\%)} = \frac{\text{Total number of dead adult insects}}{\text{Total number of release adult insects}} \text{ X } 100$$

Progeny emergence of *S. oryzae*

The plant essential oil at concentration levels of 1.0 % and in combination of 0.5 % was used to evaluate its efficacy against *S. oryzae*. Each concentration was applied in three replicates, and each replicate was contained 25 g of wheat grains. The plant essential oil of required concentration levels was socked in cotton swap and kept with wheat grains. In control treatment only water was used. Then, 10 adults of *S. oryzae* was transferred in wheat grains and plastic container were kept at 28±2^{0}C temperature, 60±5% relative humidity and a 16:8 light:dark photoperiod in BOD. The emerged progeny after hatching of eggs was recorded after 6 weeks of treatment. The reduction percentages in *S. oryzae* progeny was calculated with following equation as described by El-Lakwah *et al.* (1992).

$$\text{Reduction (\%)} = \frac{\text{MNEC} - \text{MNET}}{\text{MNEC}} \text{ X } 100$$

MNEC = Mean number of insects which emerged in the control
MNET = Number of insects which emerged in the treatment

Grain damage

After 75 days, the sample of 100 grains was taken from each treatment and control. The total number of grains was counted and % grain damage was calculated by following formula:

$$\text{Grain damage (\%)} = \frac{\text{Total number of damaged grains}}{\text{Total number of grains}} \text{ X } 100$$

Grain weight Loss

After 75 days of insect confinement, the % weight loss was calculated by following formula:

$$\text{Weight loss (\%)} = \frac{\text{Initial weight} - \text{final weight}}{\text{Initial weight}} \text{ X } 100$$

Statistical Analysis

The data recorded during the course of investigation were subjected to statistical analysis by using ANOVA for Complete Randomized Design. The data were transformed as and when required. Standard error of mean in each case and the critical difference only for significant cases were computed at 5 % level of probability.

RESULTS AND DISCUSSION

The insecticidal activities of lemongrass, eucalyptus and citrus essential oils were evaluated against *S. oryzae* adults by direct contact application method (Tables 1 & 2).

The essential oil (Eucalyptus 0.5 % + Lemon grass 0.5 %), after 21 days of the infestation of wheat grains, resulted in largest number of dead insects (96.67 %) and this treatment proved best among all the treatments. The next best essential oil (Citrus 0.5% + Eucalyptus 0.5 %) recorded adult mortality of 90.00 %, 21 days after treatment. Lemongrass 0.5 % + Citrus 0.5 %, Lemongrass essential oil (1.0 %), Eucalyptus essential oil (1.0 %) and Citrus essential oil (1.0 %) resulted in 83.33 %, 81.67 %, 73.33 % and 65.00 % adult mortality of *S. oryzae* respectively after 21 days of treatment. Results are in support with the finding of using essential oils of *Eucalyptus globules* on *S. oryzae* in the adult phase in stored wheat resulted 100 % of mortality (Rupp *et al.* 2005) and also higher adult mortality of *S. oryzae* has been reported with eucalyptus leaf powders (Deb *et al.* 2016). Similar results on-effectiveness of lemon grass essential oil (Saljoqi *et al.* 2006) and *Citrus sinensis* (Akunne *et al.*2015) extracts have been reported against *S. oryzae*.

Plant derived essential oils were found to be very effective in reduction of progeny emergence and its ranged from 54.78 to 78.06 % (Table 2). Maximum % reduction in progeny emergence 78.06 was recorded with essential oil (Lemongrass 0.5 % + Citrus 0.5 %) and 68.50 % with treatment lemongrass essential oil 75 days after treatment. Present results on progeny emergence of *S. oryzae* corroborates with the findings of Nalini *et al.* (2007) who has reported the reduction in adult progeny build up.

After 75 days of treatment used all the treatments were found significantly superior over control in decreasing the grain damage. The maximum grain damage of 25.33 % was recorded in control. Among the all treatments minimum grain damage (6.00 %) was recorded with T4 treatment and maximum grain damage (11.00 %) was found with T3 treatment. The treatments T6, T5, T2 and T1 were recorded with 7.33, 8.00, 9.33 and 10.67 % grain damage, respectively. The treatments T4 and T6 were found statistically at par to each other. The treatments T5 and T2 were found statistically at par. Patil *et al.* (2014) reported lowest infestation of seed treated with plant leaves. Sharma *et al.* (2016) obtained minimum number of damaged seeds in essential leaf oil treated seeds.

With regard to loss in weight of wheat grains after 75 days of treatment used, the data showed (Table-1) a significant difference between treatments and control. The maximum weight loss (25.50 %) of grains was found in control. The treatment T4 was found best with minimum weight loss (2.67 %). The treatments T6, T5, T2 and T1 were observed with 4.37, 6.32, 6.79 and 8.63 % weight loss, respectively. The treatment T3 recorded poor responce with weight loss (10.67 %) among all the treatments. The treatments T5 and T1 were found statistically at par to each other. Zayed (2012) evaluated mustard seeds, turmeric rhizomes, anise seeds, black pepper seeds and malathion 1% dust against rice weevil and reported the all treatments had significant desired effects on the percentages of wheat weight loss. Nalini *et al.* (2007) reported minimum loss in grain weight in botanical treated grains. Sharma *et al.* (2016) obtained minimum reduction in seed weight loss fumigated seed by essential leaf oil.

Traditional significance of study to farmers

Fumigants are being used since long to control stored grain pests but today, storage grain pest control has to face up to the economic and ecological consequences of the use of pest control measures. On other hand traditional knowledge in management of stored grain pest developed by ancient people through generations of their interaction with nature and natural resources is far better. Ancient people used plant leaves and plant parts in the past to control stored grain pests**.** keping in mind we used essential oils, t he high activity of these compounds could make it a potential substitute for fumigants in various uses in stored-product control. Plant-derived essential oils, in general, are considered minimum-risk pesticides and may be used by farmers against stored grain pest.

Table 1. Efficacy of essential oils of plants on Per cent mortality of *Sitophilus oryzae*

Treatments	Per cent Mortality		
	7 Days after treatment	14 Days after treatment	21 Days after treatment
T_1 Eucalyptus oils @1.0%	36.67 (37.24*)^c	61.67 (51.73)^c	73.33 (58.91)^c
T_2 Lemongrass oils @ 1.0%	51.67 (45.94)^d	66.67 (54.73)^d	81.67 (64.67)^d
T_3 Citrus oils @ 1.0%	31.67 (34.22)^b	58.33 (49.78)^b	65.00 (53.71)^b
T_4 Eucalyptus oils @ 0.5% + Lemongrass oils @ 0.5%	61.67 (51.73)^f	78.33 (62.27)^f	96.67 (81.37)^f
T_5 Lemongrass oils @ 0.5% + Citrus oils @ 0.5%	53.33 (46.89)^d	71.67 (57.84)^e	83.33 (65.93)^d
T_6 Citrus oils @ 0.5% + Eucalyptus oils @ 0.5%	56.67 (48.82)^e	73.33 (58.91)^e	90.00 (71.54)^e
T_7 Control	0.00 (0.00)^a	0.00 (0.00)^a	0.00 (0.00)^a
C.D. (P=0.05)	**2.77**	**2.96**	**5.55**

*Figures in parenthesis are angular transform value

Table 2. Efficacy of essential oils of plants on progeny emergence, grain damage and weight loss against *Sitophilus oryzae*

Treatments	% Reduction in Progeny Emergence			Grain Damage %	Weight loss %
	After 50 days	After 65 Days	After 75 Days		
T_1 Eucalyptus oils @1.0%	72.22 ± 2.63^c	60.04 ± 1.07^c	56.17 ±1.13^b	10.67 ± 0.93^c	8.63 ± 0.18 ^{d}
T_2 Lemongrass oils @ 1.0%	77.78 ± 2.77^c	63.64 ± 1.62^d	60.28 ± 1.21^c	9.33 ± 0.88 ^{bc}	6.97 ± 0.03 ^{c}
T_3 Citrus oils @ 1.0%	61.11 ± 2.85^b	52.73 ± 1.53^b	54.78 ± 0.61^b	11.00 ± 0.57 ^{c}	10.67 ± 0.67 ^{e}
T_4 Eucalyptus oils @ 0.5% + Lemongrass oils @ 0.5%	94.44 ± 2.46^e	78.17 ± 0.39^g	78.06 ± 1.54 ^{e}	6.00 ± 0.61 ^{a}	2.67 ± 0.16 ^{a}
T_5 Lemongrass oils @ 0.5% + Citrus oils @ 0.5%	86.11 ± 2.93^d	70.95 ± 2.93^e	67.11 ± 0.44^d	8.00 ± 0.01 ^{b}	6.32 ± 0.21^c

T_6 Citrus oils @ 0.5% + Eucalyptus oils @ 0.5%	88.89 ± 2.89^{d}	74.56 ± 2.89^{f}	68.5 ± 1.31^{d}	7.33 ± 0.33^{ab}	4.37 ± 0.18^{b}
T_7 Control	0.00^{a}	0.00^{a}	0.00^{a}	25.33 ± 1.2^{d}	25.50 ± 0.28^{f}
C.D. (P=0.05)	**8.42**	**2.35**	**1.97**	**1.99**	**0.93**

CONCLUSION

Different plant product like essential oils of leaf extract having considerable potential as insecticide compound are gaining tremendous importance for the management of insect of store products. The combination of extracted essential oils was highely toxic than using separately. The combination of essential oils (Eucalyptus + Lemon grass) proved best among the treatments and showed highest toxicity against *S. oryzae*. The progeny emergence of *S. oryzae* was significantly reduced in wheat grains treated at different doses of essential oils extracted from eucalyptus, lemongrass and citrus leaf. All the essential oils alone and in combination found significantly superior over control.

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RESEARCH ARTICLE

ASSESSING VARIABILITY IN MORPHOLOGICAL TRAITS OF JAMUN (*SYZYGIUM CUMINI* (L.) SKEELS) GENOTYPES

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Abstract: The indigenous future fruit 'Jamun' is grown throughout the tropical and subtropical regions of the country. Since vast genetic variability exists among the seedling populations, characterizing the germplasm to identify superior genotypes is essential for jamun crop improvement. In this background, morphological characterization of 14 jamun genotypes to know the variability was studied in randomized block design with three replications. Significant variability was observed for tree morphological traits such as plant height, canopy spread and leaf petiole length and fruit characters fruit length, fruit width and seed length. Variations were also observed on date of flower initiation, number of flowers and fruits set per panicle. Among the genotypes, a few with bold fruits with comparable TSS and pulp content, lesser plant height and canopy spread and early initiation of flowering such as IIHRJ-3, IIHRJ-14 and IIHRJ-12 were found as superior clones for utilizing the jamun crop improvement programs.

Keywords: Jamun, Morphological traits, Genotypes, *Syzygium cumini*

INTRODUCTION

Syzygium cumini (L.) Skeels, commonly called as 'jamun' or 'Indian black berry' is one of the most potential underutilized fruit crops, native to the Indian subcontinent. Though the species has been found growing throughout the tropical and subtropical regions of the country (Singh et al., 2016), the same has been a neglected crop until the recent past. Over the past two decades, jamun has gained the consumer attention because of its exceptional health benefits. The drupaceous fruits of jamun are either consumed as fresh or processed into many products such as juice, squash, jam etc. With the growing awareness on medicinal and nutritional properties, various jamun seed based formulations are gaining popularity among the common people.

Being highly cross pollinated by nature, huge variability exists among the seedling populations grown across the country. Variations are available in terms of fruit size, shape, pulp content, TSS and acidity which need documentation for identifying elite clones. In light of its potentiality, commercial jamun orchards are being established in the recent years. But farmers have been growing either seedlings or grafted plants of unknown yield potential due to non-availability of standard recommended varieties (Swamy *et al*., 2017). Hence, characterizing the available germplasm to identify the elite genotypes of higher yield, better fruit quality and adaptability is of utmost importance in jamun crop improvement programs. In addition to these fruit quality related traits, genotypes with dwarf tree stature, less vigorous types and off season bearing needs to be explored in view of area expansion and productivity in jamun. Keeping this in mind, the present study was taken up to know the extent of variability existing among the genotypes available in the field gene bank.

MATERIALS AND METHODS

The present research work was undertaken for morphological characterizing of 14 jamun *(Syzygium cumini* (L.) Skeels) germplasm maintained at the field gene bank of ICAR-Indian Institute of Horticultural Research, Bengaluru during 2016-17. The 15 years old jamun plants were characterized as per the minimal descriptors for fruit crops (Mahajan et al., 2000) for the tree morphological characters such as height, trunk girth, canopy spread, leaf length, width and petiole length in completely randomized block design with three replications. To know the variations in flowering related traits, date of flower initiation was visually observed; number of flowers per panicle, number of fruits per panicle and per cent fruit set were also recorded. To understand the extent of variability with respect to fruit morphological traits, ripe fruits were harvested during May-June and ten fruits from each tree were analysed for fruit weight, size, pulp content, seed size and total soluble solids (TSS). The TSS was measured using ERMA (0-32%) hand refractometer.

RESULTS

The data referring to the tree morphological characters of 14 jamun genotypes showed significant difference with respect to tree height, canopy spread and leaf petiole length (Table 1). Height of the trees ranged from 6.59 to 12.35 m. Among the accessions, IIHR9 recorded maximum tree height (12.35m) which was on par with IIHRJ-10 (11.19m), while minimum height was observed in genotypes IIHRJ-1 and IIHRJ-2(6.59 and 6.76m respectively), followed

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by IIHRJ-3 (7.06m). Though there was no significant difference for tree girth at 30 cm from ground level, the circumference ranged from 140.67m (IIHRJ-13) to 170.67m (IIHRJ10).

The tree canopy spread varied significantly in both the directions(East-west and North-south)highest tree spread in the east-west direction was noted in IIHRJ-9(10.91m) which was at par with IIHRJ-10 (9.92 m), followed by IIHRJ-8 (9.76 m), IIHRJ-5 (9.56 m) and IIHRJ-6 (9.39 m). The genotype IIHRJ-13 had significantly lower canopy spread (7.20 m) in the E-W direction followed by IIHRJ-2, IIHRJ-3 and IIHRJ-1. The maximum tree canopy in the north south (N-S) direction was recorded in the genotype IIHRJ-14 (11.31 m) which was at par with IIHRJ-2 (11.31 m). The lowest spread was recorded in IIHRJ-7 (7.05m) which was similar to IIHRJ-3 (7.89 m) and IIHRJ-9(8.03 m).

No significant difference was noted for leaf length and leaf width among the accessions. Mean leaf lamina length ranged from 11.63 cm (IIHRJ-14) to 15.53 cm (IIHRJ-10) while lamina width ranged between 5.04 cm (IIHRJ-4) and 7.53 cm (IIHRJ-9). Longest leaf petioles were present in IIHRJ-2 (2.63 cm) while leaves with shortest petioles were observed in IIHRJ-4(1.52 cm).

Table 1. Tree morphological characters of different jamun genotypes

Genotype	Tree height (m)	Tree girth (cm)	Tree canopy spread E-W (m)	Tree canopy spread N-S (m)	Leaf length (cm)	Leaf width (cm)	Leaf petiole length (cm)
IIHRJ1	6.59^{F}	148.67	7.95^{BC}	8.68^{ABCD}	15.29	6.43	2.31^{A}
IIHRJ2	6.76^{F}	144.33	7.27^{BC}	11.31^{A}	14.92	6.92	2.63^{A}
IIHRJ3	7.06^{EF}	142.33	7.78^{BC}	7.65^{D}	13.02	5.13	2.17^{A}
IIHRJ4	7.90^{CDEF}	148.00	9.05^{ABC}	7.89^{CD}	14.28	5.04	1.52^{A}
IIHRJ5	9.75^{BC}	161.00	9.56^{ABC}	7.37^{D}	13.12	6.58	2.40^{A}
IIHRJ6	9.42^{BCD}	169.00	9.39^{ABC}	8.44^{ABCD}	14.16	6.99	2.18^{A}
IIHRJ7	9.21^{BCDE}	162.33	7.88^{BC}	7.05^{D}	14.08	5.52	1.99^{A}
IIHRJ8	10.09^{BC}	146.00	9.76^{ABC}	8.08^{BCD}	14.34	5.74	1.66^{A}
IIHRJ9	12.35^{A}	158.10	10.91^{A}	8.03^{CD}	13.99	7.53	2.42^{A}
IIHRJ10	11.19^{AB}	170.67	9.92^{AB}	8.42^{ABCD}	15.53	6.95	2.03^{A}
IIHRJ11	7.33^{DEF}	144.33	8.17^{BC}	9.42^{ABCD}	12.24	6.89	2.32^{A}
IIHRJ12	8.73^{CDEF}	146.67	8.32^{ABC}	11.25^{AB}	12.92	6.06	2.18^{A}
IIHRJ13	8.24^{CDEF}	140.67	7.20^{C}	11.07^{ABC}	12.62	5.73	2.14^{A}
IIHRJ14	8.76^{CDEF}	151.67	8.76^{ABC}	11.52^{A}	11.63	5.88	1.92^{A}
p-Value	<.0001	0.2454	<.0001	<.0001	0.1590	0.0709	0.0225
CV(%)	7.15	9.73	8.69	9.91	11.70	15.19	15.31
SE(d)	0.514	12.103	0.618	0.729	1.311	0.774	0.267
Tukey HSD at 1%	2.2508	NS	2.7045	3.1908	NS	NS	1.1672

Among the 14 genotypes, variability was noticed on flowering and fruit set parameters (Table 2). Earliest initiation of flowering, in the second week of February was recorded in genotypes IIHRJ-5, IIHRJ-8, IIHRJ-3, IIHRJ-4 and IIHRJ-6 while comparatively delayed flowering was noticed in genotypes viz., IIHRJ-1 and IIHRJ-2 (second week of March). The accessions IIHRJ-7 and IIHRJ-10 did not flower and set fruits during the year of study, indicating their irregularity in bearing. The number of flowers per panicle varied from 29 (IIHRJ-2) to 96.33 (IIHRJ-14). Genotypes such as IIHRJ-6, IIHRJ-12 and IIHRJ-4 also produced more flowers per panicle (89.67, 83.00 and 81.33 respectively) while IIHRJ-8 and IIHRJ-9 had fewer flowers (35 and 33 respectively). Variations were noticed in the number of fruits produced in a panicle, ranging from 13.57 to 46.80. Number of fruits per panicle was higher in IIHRJ-14 (46.80), IIHRJ-6 (45.73) and IIHRJ-12 (43.99). The per cent fruit set ranged from 44.00 to 55.00 percent with higher fruit set in IIHRJ-

9 (55%) followed by IIHRJ-11 (54.34%) and IIHRJ-12 (53.00%).

Table 2. Flowering characters in jamun genotypes

Genotype	Date of start of flowering	Number of flowers per panicle	Number of fruits per panicle	Fruit set (%)
IIHRJ1	13.03.2016	48.33	23.68	48.99
IIHRJ2	13.03.2016	29.00	13.57	46.79
IIHRJ3	14.02.2016	41.00	19.06	46.49
IIHRJ4	14.02.2016	81.33	39.28	48.29
IIHRJ5	13.02.2016	44.00	19.36	44.00
IIHRJ6	16.02.2016	89.67	45.73	50.99
IIHRJ7	-	-	-	-
IIHRJ8	13.02.2016	35.00	14.78	42.23
IIHRJ9	08.03.2016	33.00	18.15	55.00
IIHRJ10	-	-	-	-
IIHRJ11	14.02.2016	55.67	30.25	54.34
IIHRJ12	21.02.2016	83.00	43.99	53.00
IIHRJ13	21.02.2016	68.67	32.24	46.95
IIHRJ14	21.02.2016	96.33	46.80	48.58

The data pertaining to the fruit physical traits of the genotypes are presented in (Table 3). Among the characters studied, significant variability was observed only for fruit length and fruit diameter. The accessions IIHRJ-14, IIHRJ-3 and IIHRJ-13 had maximum fruit length (3.87, 3.85 and 3.85 cm respectively) while genotype IIHRJ-8 had minimum fruit length (2.25 cm) which was on par with IIHRJ-1 (2.88 cm) and IIHRJ-4 (2.32 cm). There was no significant difference for other fruit traits such as fruit weight, seed weight, seed length, per cent pulp content and TSS. The fruit weight ranged from 5.58g (IIHRJ-6) to 11.18g (IIHRJ-2). The seed weight ranged from 1.26g (IIHRJ-8) to 2.58g (IIHRJ-2) while the seed length varied between 1.31 cm (IIHRJ-8) and 3.10 cm (IIHRJ-3). The pulp content of the genotypes ranged from 70.84 per cent (IIHRJ-11) with varying TSS from 11.25 (IIHRJ-9) to 13.62° Brix (IIHRJ-1).

Table 3. Fruit parameters of jamun genotypes

Genotype	Fruit length (cm)	Fruit diameter (cm)	Fruit weight	Seed weight (g)	Seed length (cm)	Pulp content (%)	TSS (° Brix)
IIHRJ1	2.88^{AB}	1.88^{BC}	9.95	2.51	1.99	74.65 (59.77)	13.62
IIHRJ2	3.46^{AB}	2.52^{ABC}	11.18	2.58	2.44	76.61 (61.09)	12.42
IIHRJ3	3.85^{A}	2.97^{ABC}	10.04	1.85	3.10	78.93 (62.91)	11.33
IIHRJ4	2.32^{B}	1.77^{C}	7.02	1.72	1.40	74.96 (60.05)	12.65
IIHRJ5	3.06^{AB}	2.27^{ABC}	7.37	1.95	2.43	72.95 (58.69)	12.25
IIHRJ6	3.53^{AB}	2.60^{ABC}	5.58	1.43	3.02	74.27 (59.54)	11.50
IIHRJ8	2.25^{B}	1.68^{C}	6.10	1.26	1.31	79.24 (62.89)	11.50

IIHRJ9	2.70^{AB}	1.63^{C}	9.47	2.56	1.74	72.32 (58.26)	11.25
IIHRJ11	3.66^{AB}	3.01^{ABC}	8.49	2.33	3.08	70.84 (57.43)	11.45
IIHRJ12	3.72^{AB}	3.31^{AB}	8.26	2.39	2.76	71.38 (57.69)	11.65
IIHRJ13	3.85^{A}	3.28^{AB}	9.60	2.31	2.70	76.00 (60.68)	11.75
IIHRJ14	3.87^{A}	3.42^{A}	8.66	2.36	2.50	72.79 (58.56)	11.40
p-Value	0.0046	0.0021	0.3011	0.0471	0.0369	0.0451	0.7694
CV(%)	11.14	14.74	24.11	17.92	21.36	5.238	10.56
SE(d)	0.363	0.372	2.043	0.377	0.506	-	1.256
Tukey HSD at 1%	1.467	1.5037	NS	NS	NS	NS	NS

DISCUSSION

In perennial fruit crops like jamun, elite clonal selection is majorly adopted for conventional crop improvement. While identifying the elite ones with better yield and fruit quality, emphasis needs to be given for dwarf types with compact canopy for effective utilization of limited land available. The genotype IIHRJ-3 having bolder fruits of higher TSS and pulp content could be a promising clone owing to its smaller tree stature (with lesser plant height and canopy spread) and early onset of flower initiation. With higher number of fruits per panicle, genotypes IIHRJ-14 and IIHRJ-12 are also found superior due to comparable fruit quality and less vigorous plants and early flowering. Even though the other genotypes included in the study possessed fruits of similar size and quality, the robust or highly vigorous growth habit make them unappealing for selection programs. Several other studies have been reported on physico-chemical characterization of jamun collections across the country by various researchers viz., Singh and Kaur (2016), Devi *et al*. (2016), Swamy *et al*. (2017) and Ningot *et al*. (2017).

CONCLUSIONS

Among the fourteen genotypes characterized, variability was observed for tree characters like tree height, plant canopy spread in E-W and N-S directions, and leaf petiole length. Variations were also observed among the fruit characters such as fruit weight, seed weight, pulp content and TSS, though not significant. Among the genotypes, a few with bold fruits, comparable TSS and pulp content, lesser plant height, low canopy spread and early initiation of flowering such as IIHRJ-3, IIHRJ-14 and IIHRJ-12 were found as superior clones for utilizing the jamun crop improvement programs.

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RESEARCH ARTICLE

ASSOCIATION BETWEEN FARMERS' PERSONALITY TRAITS AND AWARENESS TOWARDS SOIL PARAMETERS

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Abstract: The present study was carried out to study the socio-economic profile and awareness level about soil parameters of respondents. Haryana is divided into two Agro-Climatic zones such as North Eastern Zone and South Western Zone. From each zone two districts will be selected purposively viz. Kurukshetra and Karnal from North-Eastern zone and Bhiwani and Rewari from South-Western zone. Total sample size of 240 respondents was selected for collecting the data. The majority of the respondents were middle age group, 90 per cent were literate from primary to graduate or above and maximum 49.17 percent respondents had medium Socio-economic status (SES). Majority of the respondents had low mass media exposure and extension contacts. Respondents had high awareness about soil texture, soil colour and crops which are suitable for their soil. Education and SES were found significantly correlated with awareness of respondents about soil parameters.

Keywords: Awareness level, Soil parameters, Correlation, Farmers

INTRODUCTION

Soil is a mixture of organic matter, minerals, gases, liquids and organism that together support life. Earth's body of soil is the pedosphere, which has four important functions: it is a medium for plant growth; it is a means of water storage, supply and purification; it is a modifier of Earth's atmosphere; it is a habitat for organisms; all of which, in turn, modify the soil. The mineral components of soil are sand, silt and clay, and their relative proportions determine a soil's texture. Properties that are influenced by soil texture include porosity, permeability, infiltration, shrink-swell rate, water-holding capacity, and susceptibility to erosion. At the next larger scale, soil structures called peds or more commonly soil aggregates. Soil structure often gives clues to its texture, organic matter content, biological activity, past soil evolution, human use, and the chemical and mineralogical conditions under which the soil formed. While texture is defined by the mineral component of a soil and is an innate property of the soil that does not change with agricultural activities, soil structure can be improved or destroyed by the choice and timing of farming practices. Soil temperature and colour are self-defining. Resistivity refers to the resistance to conduction of electric currents (Anonymous, 2018). Soil pH generally refers to the degree of soil acidity or alkalinity. The pH scale ranges from 0 to 14; a pH of 7 is considered neutral. If pH values are greater than 7, the solution is considered basic or alkaline; if they are below 7, the solution is acidic.

Soil quality is often referred to as "Soil Health" because of objectives similar to the monitoring and maintenance of human health. The soil quality concept emphasizes an ecological approach to land management. Management actions don't have simple, single effects in complex systems, such as soil. Management has multiple effects, both direct and indirect. For example, tillage is used to loosen surface soil, prepare the seedbed, and control weeds and pests. But tillage can also break up soil structure, speed the decomposition and loss of organic matter, increase the threat of erosion, destroy the habitat of helpful organisms, and cause compaction (Anonymous, 2011).

Soil quality assessment methods provide a framework for comparing management tradeoffs and deciding which management options provide the greatest good, whether for one's farming operation or at a watershed or regional scale.

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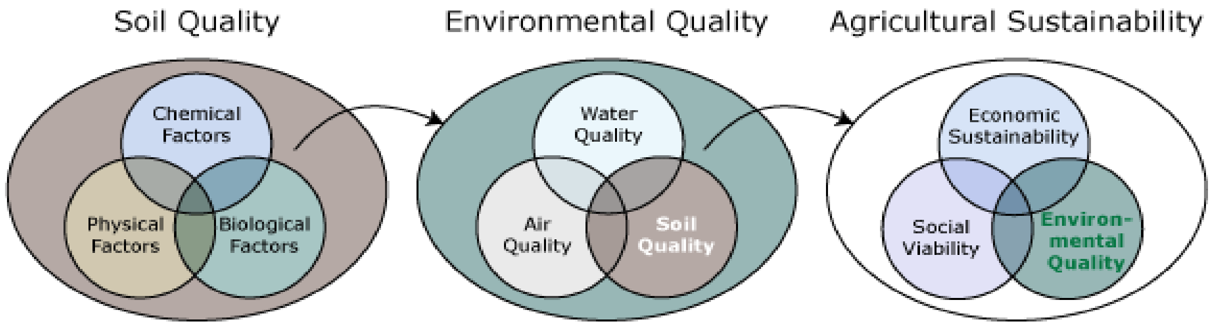

Among the different categories, lands under cultivation face the biggest problem followed by grazing land and pastures, forests, barren lands, and unculturable lands in decreasing order. A healthy resource base is essential to agriculture and the sector's ability to drive household and national economic development. In the coming years, most of the increase in population will occur in developing world and will account for about 85 per cent of the increase in demand for cereals and meat. Providing enough food for rapidly increasing population in developing countries like India is a continuing challenge for agricultural professionals. Due to limited availability of additional land for crop production, along with declining yield growth for major food crops has heightened concerns about agriculture's ability to feed its teeming population.

MATERIALS AND METHODS

The study was conducted in Haryana state. Haryana is divided into two Agro-Climatic zones such as North Eastern Zone and South Western Zone. From each zone two districts will be selected purposively viz. Kurukshetra and Karnal from North-Eastern zone and Bhiwani and Rewari from South-Western zone. Two blocks Thanesar and Babain from Kurukshetra; Karnal and Indri from Karnal; Siwani and Kairu from Bhiwani; and Khol and Bawal from Rewari will be selected purposively having highest nutrient deficiency and 30 respondents will be selected randomly from each block. Thus, a total of 240 farmers will be interviewed for this study.
The data was collected with the help of well-structured and pre-tested interview schedule. The responses were obtained on three-point continuum scale in case of awareness (Not aware, Aware and fully aware). Keeping in view the requirement of the study, frequency, mean, percentage, rank, correlation coefficient and multiple regressions were calculated for the purpose of analysis and interpretation of data.

RESULTS AND DISCUSSION

Farmers' awareness towards soil parameters

Awareness is the state or ability to perceive, to feel, or to be conscious of events, objects or sensory patterns. In this level of consciousness, sense data can be confirmed by an observer without necessarily implying understanding. More broadly, it is the state or quality of being aware of something. This variable is being explored in terms of awareness about soil health management practices.
It is evident from the Table 1 that respondents had high awareness about 'soil texture' ranked 1st position with weighted mean score (WMS) 2.79, followed by 'soil colour' and 'crops which are suitable for your soil' ranked 2nd and 3rd position with WMS 2.01 and 1.80, respectively. Whereas, 'availability of nutrient in soil surface up to 6 inch and sub-surface soil' and 'soil fertility status' were ranked 4th and 5th position with WMS 1.50 and 1.40, respectively. Both 'aware about micro and major nutrients' and 'in every 3 years Zn should be applied in the field' ranked 6th position with WMS 1.29 (Fig. 1).
On the other hand, respondents had low awareness about 'organic matter (organic carbon) content of soil', 'pH of soil', 'the difference between soil structure and soil texture', 'effect of puddling on pH' and 'erosion promoting and controlling crops'. Difference between soil structure and soil texture was not known by respondents because these are technical terms which are not earlier discussed with farmers by anyone, they also not aware about the effect of puddling on pH because pH is a scientific term or if aware, they are not know that pH is related with availability of nutrients. Study got strength from the research findings of Mousavi, *et al.* (2009).

Table 1. Farmers' awareness towards soil parameters (N=240)

S. No.	Statements	Fully aware (%)	Aware (%)	Not aware (%)	Total Weighted Score	Weighted Mean Score	Rank Order
1	Are you aware about soil colour?	49 (20.42%)	144 (60%)	47 (19.58%)	482	2.01	II
2	Do you know your soil texture (light or heavy)?	190 (79.17%)	50 (20.83%)	00 (0.00%)	670	2.79	I
3	Do you know about PH of your	0 (0.00%)	48	192	288	1.20	VIII

	soil?		(20%)	(80%)			
4	Do you know the difference between soil structure and soil texture?	0 (0.00%)	0 (0.00%)	240 (100%)	240	1.00	IX
5	Do you know tillage/puddling change you soil structure?	24 (10%)	48 (20%)	168 (70%)	336	1.40	V
6	Are you aware about effect of puddling on PH?	0 (0.00%)	0 (0.00%)	240 (100%)	240	1.00	IX
7	Do you aware about the organic matter (organic carbon) content of soil?	0 (0.00%)	52 (21.67%)	188 (78.33%)	292	1.22	VII
8	Do you know the availability of nutrient for plants in surface (6 inch) and sub-surface soil?	25 (10.42%)	70 (29.17%)	145 (60.42%)	360	1.50	IV
9	Do you aware about crops which are suitable for your soil?	24 (10%)	144 (60%)	72 (30%)	432	1.80	III
10	Do you know your soil fertility status?	24 (10%)	48 (20%)	168 (70%)	336	1.40	V
11	Do you aware about micro and major nutrients?	0 (0.00%)	70 (29.17%)	170 (70.83%)	310	1.29	VI
12	Do you know in every 3 years Zn should be applied in the field?	0 (0.00%)	96 (40%)	144 (60%)	336	1.40	VI
13	Are you aware about erosion promoting and controlling crops?	0 (0.00%)	0 (0.00%)	240 (100%)	240	1.00	IX

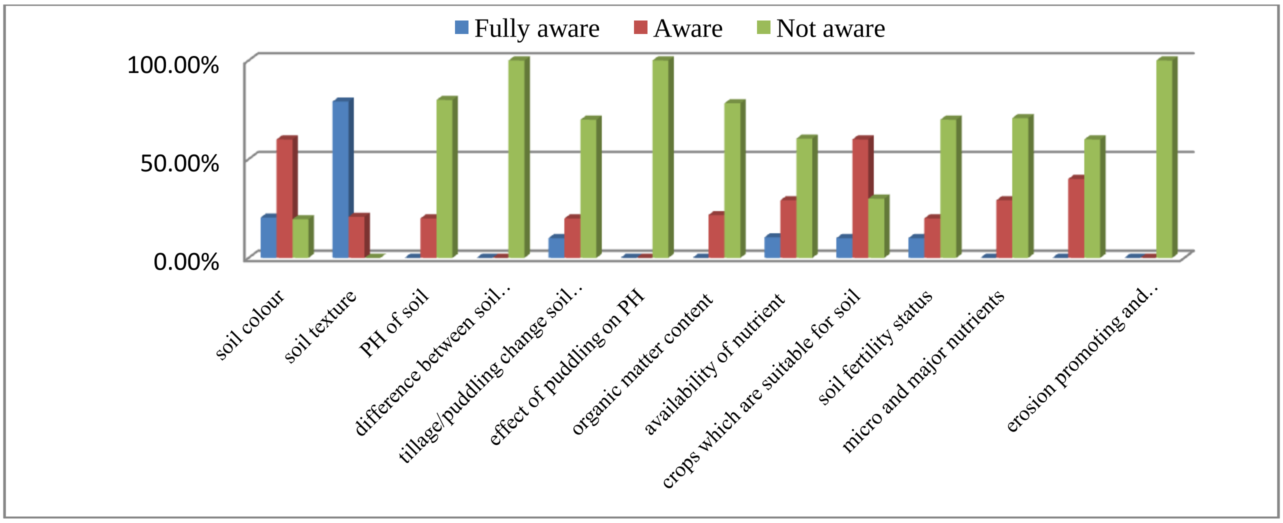

Fig.1. Farmers' awareness towards soil parameters

Relationship of respondents' personality traits with their awareness level about soil parameters

Table 2 showed that correlation coefficient between the different personality traits like education and SES with the awareness level had significant correlation at 0.05 level of probability. However, remaining traits namely, age, caste, land holding, farm inputs, farm equipments, irrigation, crop rotation, cropping pattern, agro-chemicals, SHC, mass media exposure, and extension contacts did not show any significant association with the awareness towards soil parameters (Fig. 2).

While in case of the partial regression coefficient, the farmers' SES, and extension contacts were found significant at 0.05 level of probability, whereas, age, education, caste, land holding, farm inputs, farm equipments, irrigation, cropping system, crop rotation, agro-chemicals, SHC and MME did not significantly contribute to the awareness towards soil parameters. These finding were found to partially support by the reports of Rohilla (2018) and Rajashekar *et al.* (2017).

It was further revealed that all the independent variables jointly contributed 11.00 per cent variation in the awareness of the respondents regarding soil parameters when other factors were remaining constant. This implies that only 11.00 per cent of the variation in the dependent variable was due to these variables included in the study and remaining 89.00 per cent variations is due to other variables.

Table 2. Correlation and regression between personality traits and their awareness level

Sr. No.	Variables	Correlation Coefficient	Regression Coefficient	't' values
1	Age	0.077^{NS}	0.007	0.429
2	Education	-0.162*	-0.199	-1.845

3	Caste	0.006^{NS}	-0.111	-0.639
4	SES	0.197**	0.072	3.290*
5	Land Holding	-0.030^{NS}	-0.027	-0.201
6	Farm Inputs	0.045^{NS}	0.070	0.549
7	Farm Equipments	-0.024^{NS}	-0.061	-0.580
8	Irrigation	-0.030^{NS}	-0.256	-0.723
9	Cropping system	-0.047^{NS}	-0.323	-0.710
10	Crop rotation	0.104^{NS}	0.240	1.655
11	Agro- chemicals	0.092^{NS}	0.517	1.590
12	SHC	0.049^{NS}	0.096	0.652
13	MME	0.082^{NS}	0.058	0.796
14	Ext. Contact	0.104^{NS}	0.056	1.947*

Dependent variable- Awareness
*Significant at 0.05 levels
R^2=0.110

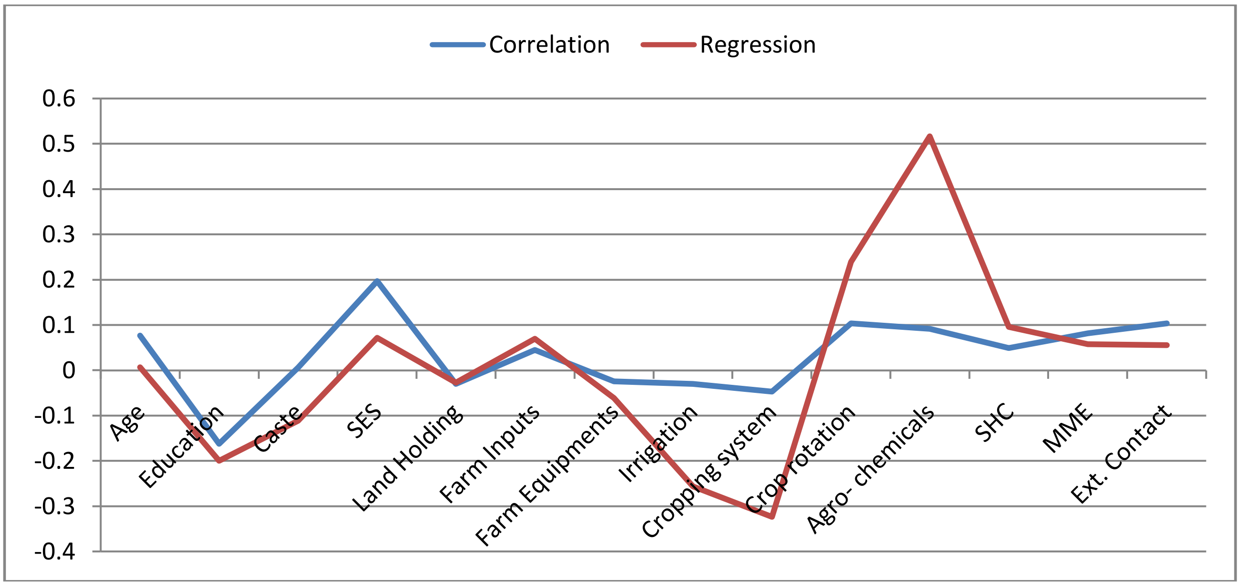

Fig.2. Correlation and regression between personality traits and their awareness level

CONCLUSION

The study revealed that there was a gap in awareness level of soil parameters. Increasing the awareness about soil parameters helps in management of soil for sustainable agriculture. Stagnation and decline in yield due to degradation of soil is one of the major constrains to current agriculture. Hence, to make the soil healthy, there is an immense need to motivate and encourage the farmers by organizing continuous trainings, lectures, campaigns and demonstrations about the soil parameters and properties.

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RESEARCH ARTICLE

SEASONAL INCIDENCE OF DIAMOND BACK MOTH, *PLUTELLA XYLOSTELLA* (L.) ON CABBAGE AT NORTHERN HILLS OF CHHATTISGARH

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Abstract: Seasonal incidence of diamondback moth *Plutella xylostella* L. on cabbage was conducted at three spots during winter season 2017-18. The result of experiments revealed that the pest was appeared from the 4th SMW (in the month of last January) with an average population of 1.7 larvae/plants at all locations and remained in the fields until the 14th SMW (in the month of April). The peak population of DBM was observed in 11th SMW with average population 7.4 larvae/plants at maximum and minimum temperature, 31.6^{o}C and 16.2^{o}C and relative humidity 69 per cent, respectively, thereafter the population started declining. The larval activity suddenly decreased with 0.7 larvae/plants in the 14th SMW (in the second week of April), during the period maximum and minimum temperature were increased and relative humidity also decreased.

Keywords: Cabbage, Diamondback moth, Seasonal incidence, Chhattisgarh

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata*) is one of the most important cruciferous vegetable crops in India and second largest producer of cabbage in the world, next to China. Countrywide, it is grown in an area of 407 hectare with an annual production of 8971mt ranking second to cauliflower in area but topping in production among cole crops (NHB 2016). The area of Chhattisgarh is 12913.82 ha, production is 217980.83mt and productivity is 16.15mt in 2015-16 (Tegar *et al.*, 2016).

It is the most popular vegetable around the world in respect of area, production and availability, almost round the year and occupies the pride place among cole crops due to its delicious taste, flavour and nutritive value. It is grown for heads which are used as vegetable, eaten raw and frequently preserved as sauerkraut or pickle.

This cole crop is attacked by many insect pest *i.e.* aphid, semilooper, head borer, diamondback moth etc. The diamondback moth (DBM), *Plutella xylostella* L. (Lepidoptera: Plutelidae), is a major and serious pest of crucifer crops as worldwide (You and Wei, 2007). Fletcher (1914) recorded this pest for the first time in India on cruciferous vegetable and perusal of literature revealed that the pest is distributed all over India. Krishnakumar *et al.* (1984) reported 52 per cent loss in marketable yield of cabbage due to the attack of *P. xylostella* (L.). While Srinivasan (1984) reported 90-92 per cent loss could occur if cabbage is left unprotected and also vary from 30-100 per cent (Lingappa *et al.*, 2000). In India, Krishnamoorthy (2000) has also reported a 52 per cent reduction in yield and the losses to DBM is estimated to be $ 16 million annually in a cultivated area of 5, 01,700 ha (Mohan and Gujar, 2003).

DBM has developed resistance to as many as 73 insecticides (Zhao *et al.*, 2002; Phani Kumar and Gujar, 2005). Studies on alternative control methods to ensure environmental and food safety have become an important task for agriculture professionals. Now a day's ecofriendly pest management has gained worldwide attention. It is not only effective against crop pests but also safer to beneficial insects and environment. Chemical insecticides usually play a major role in management of *P. xylostella*. Currently growers are facing serious threats from this pest, particularly due to insecticide resistance and ineffective biological control.

So we need to adopt most effective management tactics that prevent the infestation and losses without harming beneficial insects. Keeping in mind the above facts, present investigation was carried out.

MATERIALS AND METHODS

The present investigation entitled''Seasonal incidence of diamondback moth *Plutella xylostella* (L.) on cabbage at northern hills of Chhattisgarh''was conducted at Research cum Instructional farm of RMD College of Agriculture and Research Station, Ambikapur during winter season 2017-18.

In the field experiment, each plot was properly demarcated during the seasons with the following technical programme. In a plot of 10x10 m^2 area, Cabbage variety "Green Challenger" was sown. An observation of DBM population was recorded from their appearance on plants till harvest at different intervals. Ten plants were selected randomly at each 3 spots for the study of diamondback moth by the direct visual counting method at weekly interval during morning hours, without disturbing the pest fauna. The observed population was correlated with the meteorological data during the study period.

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RESULTS AND DISCUSSION

Observations were recorded at three spots at northern hill zone of Chhattisgarh from January, soon after the transplantation of cabbage seedling for the seasonal incidence of the diamondback moth is presented in Table No. 1.

The pest first appeared in the 4th SMW (Standard Meteorological Week) at all three spots and remained in the fields until the 14th SMW. The average larval population 1.7 larvae/plants were recorded during the 4th SMW in the last week of January, when maximum temperature 24.6°C, minimum temperature 6.2°C and relative humidity 86 per cent, respectively.

The larval population after the rainy day suddenly increased to 3.4 larvae/plant during the 8th SMW (1st week of March) when the maximum temperature, minimum temperature and relative humidity were 30.0°C, 13.5°C and 80 per cent, respectively.

The peak population of 7.4 larvae/plants were observed at 11th SMW in the 4th week of March at 31.6°C maximum and 16.2°C minimum temperature and 69 per cent relative humidity, thereafter the population started declining.

The larval activity suddenly decreased with an average population 0.7 larvae/plant during the 14th SMW (second week of April) at 33.8°C maximum temperature, 19.1°C minimum temperature and 67 per cent relative humidity, respectively.

Finding the result accordance Chaudhuri *et al*. (2001) revealed the larval population of diamondback moth maximum in the last week of March. The larval population showed positive correlation with average temperature, relative humidity and rainfall.

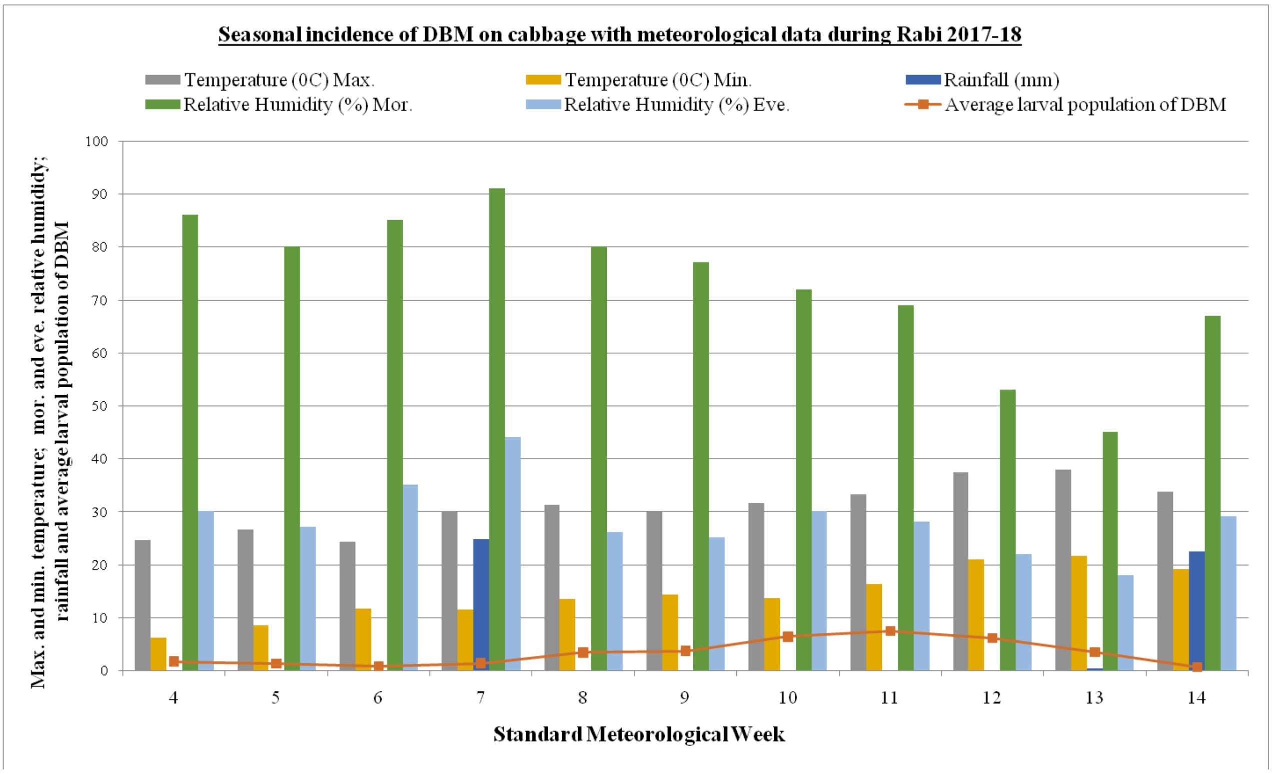
Iga (1985), Lee (1986), Srinivasan and Rao (1987) reported that the maximum activity of the diamondback moth was found in winter season, when the maximum and minimum temperature ranged between 30°C and 10°C and morning and evening relative humidity was 85 to 90 per cent. Patel (2002) also reported that the maximum activity was during winter season, when the maximum and minimum temperature was recorded to be 27.5 and 9.4°C, morning and evening relative humidity was 87 and 29 per cent.

Similarly, Devi and Raj (1991) had reported that the maximum activity of the diamondback moth was during the month of March and April.

The current findings have been observed as similar in trend. The peak period of cabbage diamondback moth was observed during the month of March, when the maximum and minimum temperature was recorded to be 31.6°C to 16.2°C, morning and evening relative humidity was 69 to 28 per cent.

Table 1. Seasonal incidence of diamondback moth *Plutella xylostella* (L.) on cabbage and meteorological data during 2017-2018.

SMW	Date of Observation	Larval Population of Diamondback Moth			Total	Overall Mean	Temperature (°C)		Rainfall (mm)	Relative Humidity (%)	
		Spot 1	Spot 2	Spot 3			Max.	Min.		Mor.	Eve.
4	31/1/2018	1.5	1.6	2.0	5.1	1.7	24.6	6.2	0.0	86	30
5	7/2/2018	1.3	1.3	1.3	3.9	1.3	26.6	8.4	0.0	80	27
6	15/2/2018	0.7	1.0	0.9	2.6	0.8	26.5	11.6	0.0	85	35
7	22/2/2018	1.4	1.1	1.8	4.3	1.4	24.3	11.4	24.8	91	44
8	1/3/2018	2.7	3.1	4.6	10.4	3.4	30.0	13.5	0.0	80	26
9	7/3/2018	5.4	0.5	5.3	11.2	3.7	31.3	14.3	0.0	77	25
10	14/3/2018	6.4	7.1	5.9	19.4	6.4	29.9	13.7	0.0	72	30
11	21/3/2018	8.0	6.2	8.2	22.4	7.4	31.6	16.2	0.0	69	28
12	28/3/2018	6.4	5.9	6.2	18.5	6.1	33.3	15.6	0.0	70	20
13	4/4/2018	3.4	3.6	3.5	10.5	3.5	36.3	17.0	0.0	64	20
14	11/4/2018	0.6	0.8	0.7	2.1	0.7	33.8	19.1	22.4	67	29



CONCLUSION

The larval population of diamondback moth was started from the 4th SMW in the month of last January to 14th SMW in the second week of April at all locations. The peak population was observed in 11th SMW in the fourth week of March, thereafter the population started declining. The larval activity suddenly decreased in the 14th SMW in the second week of April on the cabbage crop. Hence, maximum plant protection measures should be taken up against the diamondback moth during the month of March under northern hills region of Chhattisgarh.

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