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RESEARCH ARTICLES

RESEARCH ARTICLE

EFFECT OF SEED TREATMENT ON GERMINATION AND SURVIVABILITY OF CUSTARD APPLE

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Abstract: The experiment comprised of 14 treatments, viz. T_1 (control/without water soaking), T_2 (Water soaking), Gibberellic acid concentrations -T_3 (200 ppm), T_4 (300 ppm), T_5 (400 ppm), and chemicals viz.T_6 (Thiourea 0.5%), T_7 (Thiourea 0.75%), T_8 (Thiourea 1.00%), T_9 (KNO_3 0.5%), T_{10} (KNO_3 0.75%), T_{11} (KNO_3 1.00%), T_{12} (Sodium thiosulphet-150 ppm), T_{13} (Sodium thiosulphet-200ppm), T_{14} (Sodium thiosulphet-250 ppm) was conducted to study the effect of chemicals and plant growth regulators on germination, vigour of seedling and survivability of custard apple. Among the various treatments, GA_3, concentration at 400 ppm (T_5) was proved superior in respect to germination of custard apple seed as well as growth parameter and survival of custard apple seedling.

Keywords: Custard Apple, Chemicals, Plant growth regulators, Germination, Survival

INTRODUCTION

Custard Apple (*Annona squamosa* L.) belongs to the family Annonaceae and is one of the finest fruits introduced in India from tropical America. It is also found in wild form in many parts of India. In India, custard apple occupies an area of 29.87 thousand ha with production of 228.37 MT (Anonymous, 2015). It is found growing almost in all the tropical and sub tropical regions mostly in wild form .Andhra Pradesh is the major custard apple growing state along with Tamil Nadu, Orissa, Assam, U.P., M.P., Bihar and Rajasthan. Setten and Koek-Noorman (1992) observed that Annonaceae seeds undergoing dispersal have a small embryo that is considered underdeveloped and immature.

Seed germination of custard apple is uneven and irregular making sexual propagation difficult. Much experimental evidences support the concepts that specific endogenous growth promoting and inhibiting compounds are involved directly in the control of seed development, dormancy and germination (Black, 1980). Custard apple requires 35-50 days for potential germination (Hernandez, 1983). Irregular germination, in custard apple seeds may be due to dormancy or due to hard seed coat. Very limited work has been carried out on this aspect in India and in different parts of the world indicating, the utility of GA_3 from 150-500ppm and chemicals for getting better germination of custard apple seeds (Banker, 1987; Stino et al.,1996, Pawshe et al., 1997; Ratan and Reddy, 2004). Therefore, pre treatment of custard apple seed with water, different organics and chemicals is very important to improve germination. Considering the above problem the investigation was conducted to find out effect of water soaking, PGR and chemicals on seed germination and survivability of custard apple.

MATERIALS AND METHODS

The investigation was conducted at Horticulture Farm Maharajpur, Department of Horticulture, College of Agriculture, JNKVV, Jabalpur (M.P.).during 2014-15 under poly house condition in Randomized Block Design with three replication.The seeds were treated with chemicals and PGR as per treatments. The experiment comprised of 14 treatments viz. Without water soaking (control) -T_1, Water soaking- T_2, GA_3 -200 ppm- T_3, GA_3 -300 ppm- T_4, GA_3 -400 ppm- T_5, Thiourea -0.5 % - T_6, Thiourea -0.75 % - T_7, Thiourea -1.00 % - T_8, KNO_3 -0.5 % - T_9, KNO_3 -0.75 % - T_{10}, KNO_3-1.00 % - T_{11}, Sodium Thiosulphate -150 ppm- T_{12}, Sodium Thiosulphate -200 ppm - T_{13}, Sodium Thiosulphate-250 ppm- T_{14}. The seeds were soaked in water and as well as in GA_3 and different chemical solutions for 24 hours and grown in polybags under the polyhouse. One seed per poly bag was sown at 2-2.5 cm depth. The growth parameters were recorded at 30, 60, 90, 120 and 150 days after sowing. Five plants were randomly selected for observations and mean value was computed. The data were analyzed using standard statistical methods. (Panse and Sukhatme,1985).The length was measured with metre scale, width was with verniere calipers and weight with electronic weighing machine. The germination in each treatment was recorded at 60 days after sowing. Number of seedlings were counted and expressed as germination percentage.

$$\text{Germination (\%)} = \frac{\text{Total no. of seeds germinated}}{\text{Total no of seeds sown}} \times 100$$

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The survival percentage of each treatment was recorded at 150 days after seed sowing.

$$\text{Survival percentage of seedlings} = \frac{\text{No. of survived seedling}}{\text{Total no. of seedlings}} \times 100$$

RESULT AND DISCUSSION

Days taken to start germination

The data pertaining to days taken to start germination revealed that almost all the treatments showed significant effect on days taken to start germination of seed over T_1 (control). The minimum days (29.73) were taken to germinate the seed of custard apple under T_5 which was found statistically at par with T_{11} (30.47), T_{10} (31.13), T_{12} (31.33), T_4 (31.40), T_3 (31.67), T_6 (31.87) T_7 (32.13) T_9 (32.27) and T_8 (32.53). The maximum days (38.00) were taken to start germination under T_1 (control). The increase in germination was due to GA_3. GA_3 has antagonistic effect on germination inhibitors (Brain and Heming 1958; Wareing et al., 1968) and endogenous gibberellins were reported to increase due to soaking (Mathur et al., 1971). GA_3 helps in synthesis of á-amylase which converts the starch into simple sugars. These sugars provide energy that is required for various metabolic and physiological activities. The result is in agreement with the findings of Shanmugavelu (1968) in jackfruit, Gupta (1989) in citrus, Babu et al. (2004) in papaya and Ratan and Reddy (2004) who reported that the GA_3 400 ppm took minimum time to germinate the seeds of Custard apple. The findings are supported by Pillewan et al. (1997) treatment with thiourea at 150 ppm for 24 hrs on higher seed germination. Ratan and Reddy (2003) reported that the Seed germination was highest with seed soaking at 1% potassium nitrate for 24 h.

Days taken to 50% germination

The data pertaining to days taken to 50% germination clearly showed that all the treatments significantly affected the days taken to 50% germination of seed over T_1 (control). GA_3 concentration of 400ppm recorded minimum days (37.40) for 50% germination which was statistically at par with T_{11} (37.60), T_{10} (37.93), T_{12} (38.40), T_4 (38.47), T_3 (38.53), T_6 (38.60), T_7 (38.67), T_9 (38.73), T_8 (38.80), T_{13} (39.07) and T_{14} (39.87). The maximum days (45.13) to achieve 50% germination were noted under T_1 (control).Initiation of seed germination was significantly affected by gibberellic acid. The findings are supported by Ynoue et al. (1999) who reported that the GA_3 150 ppm reduced the average time of germination on kiwi fruit seeds.

Percentage of germination in each treatment at 60 days

Data revealed that almost all the treatments showed significant effect on percentage of germination of seed at 60 DAS over T_1 (control). The maximum percentage of seeds germination (86.67%) was noted at 60 days after sowing under T_5 (GA_3 400ppm) which was found statistically at par with T_{11} (85.00%), T_{10} (83.33%), T_{12} (81.67%), T_4 (80.00%), T_3 (78.33%) and T_6 (77.07%) and T_7 (76.67). Whereas, the minimum percentage of seeds germination (64.41%) was under noted T_1 (control).These findings may be due to GA_3, which would have triggered the activity of specific enzymes that promoted early germination, such as α-amylase, which have brought an increase in availability of starch assimilation. Similar findings were reported by Wagh et al. (1998). And Plant growth regulators and some chemicals are widely used in increasing the seed germination percentage and for healthy growth. Similar findings were reported by Parmar et al. (2016).

Height of shoot (cm)

The data on length of shoots recorded at 60, 90, 120, 150 days after sowing showed that almost all the treatments showed significant effect on length of shoots over T_1 (control) at 60, 90, 120 and 150 DAS. The significantly maximum shoot length of 6.54, 14.99, 23.64 and 38.49 cm were noted under T_5 (GA_3 400ppm) at 60, 90, 120 and 150 DAS, respectively. The minimum shoot length 4.67, 10.57, 15.99 and 22.77 cm were recorded under T_1 (without water soaking) at 60, 90, 120 and 150 days after seed sowing, respectively closely followed by T_2 treatments. Basically, plant height is a genetically controlled character. But, several studies have indicated that plant height can be increased by application of synthetic plant growth regulators. However, in the present investigation a significant difference in plant height was noticed by the application of different concentration of GA_3. GA_3 treatment apart from improving germination also increased the subsequent growth of seedling. This may be attributed to cell multiplication and elongation of cells in the cambium tissue of internodal region by GA_3 apparently activating the metabolic processes or nullifying the effect of an inhibitor on growth. Increase in shoot height due to GA_3 has also been reported by Ratan and Reddy (2004). Rajamanickam *et al*. (2004) reported that KNO_3, 0.5% KNO3 + 200 ppm GA_3 and 1% thiourea and sown on a sand medium.

Number of leaves per seedling

The data pertaining to number of leaves per seedling recorded at 60, 90, 120, 150 days after sowing showed that all the treatments have significant effect on number of leaves over T_1 at 60, 90, 120 and 150 DAS. The maximum number of leaves 7.63, 14.50, 27.13 and 38.57 were noted under T_5 (GA_3 400ppm) at 60, 90, 120 and 150 DAS, respectively. The minimum number of leaves of 5.27, 9.53,16.30 and 22.33 leaves were recorded under T_1 (without water soaking) at 60, 90, 120 and 150 days after seed sowing, respectively. The production of more

number of leaves in GA_3 treatments may be due to the vigorous growth and more number of branches induced by GA_3 facilitates better harvest of sunshine by the plants to produce more number of leaves. Similar findings were also reported by Venkata Rao and Reddy (2005) in mango.

Girth of stem (mm)

Data pertaining to girth of stem as affected by different days showed that varies treatments had significant effect on stem girth over T_1 (control) at 60, 90, 120 and 150 DAS. The maximum stem girth of 1.79, 2.52, 3.17 and 4.08 (mm) were recorded under T_5 (GA_3 400ppm) at 60, 90, 120 and 150 days after sowing, respectively at 150 DAS. The maximum girth (4.08) noted under T_5 was found at par with T_{11} (3.88). The minimum stem girth of 1.19, 1.60, 2.77 and 3.10(mm) were recorded under T_1 (without water soaking) at 60, 90, 120 and 150 days after sowing. The increase in seedling girth by application of gibberellic acid was also reported by Venkata Rao and Reddy (2005) in mango.

Length of seedling (cm)

That various treatments showed significant effect on length of seedling over control ($T_{1)}$ at 150 days after sowing. The maximum seedling height of (61.63 cm) were recorded when seeds soaked in 400ppm concentration of GA_3 (T_5), whereas, minimum height of seedlings (38.92 cm) was recorded under control (T_1),. Gibberellins are well known for inter-nodal cell elongation, thereby leading to increase in seedling length. These findings are supported by Ratan and Reddy (2004).

Length of root (cm)

A perusal of data revealed that the different treatments showed significant effect on root length over T_1 (control) after 150 days. The maximum length of root (23.14 cm) was recorded under T_5 which was at par with T_{11} (21.44 cm), T_{10} (21.43 cm) T_{12} (20.71 cm) and T_4 (20.65 cm) while minimum length of root (16.15 cm) was recorded under T_1 (control).Exogenous application of GA_3 induced the activity of gluconeogenic enzymes during early stages of seed germination and this could be the reason for improved germination and vigour characteristics that is reflected in terms of increase in root length. Similar findings were also reported by Wagh et al. (1998). Rajamanickam et al. (2004) reported that KNO_3, 0.5% KNO_3 + 200 ppm $GA_{3.}$ were recorded maximum root length in amla.

Number of roots per seedling

The data revealed that various treatments showed significant effect on number of roots over T_1 (control) after 150 days. The maximum number of (48.70) roots per seedling was recorded under T_5 which was at par with T_{11} (46.47), T_{10} (45.73), T_{12} (43.80) and T_4 (41.13) while minimum number of root was recorded under T_1 (31.27). Vigrous root growth due to GA_3 might have resulted in more production of photosynthates and their translocation through phloem to the root zone, which might be responsible for improving the root growth. Similar findings were reported by Wagh et al. (1998).

Fresh and dry weight of shoot and roots (g)

A perusal of data indicated that the fresh weight of roots was significantly affected by different treatments over T_1 (control).The maximum fresh weight of roots (1.92 g) was recorded under T_5 and found significantly at par with T_{11} (1.75 g), while the minimum fresh weight of roots (1.09 g) was noted under T_1 (control).

It is also clear that dry weight of roots was significantly affected by the various treatments. The maximum dry weight of roots was (0.66 g) was recorded under treatment T_5 which was found statistically at par with T_{11} (0.59 g), T_{10} (0.56 g) and T_{12} (0.52 g) while minimum (0.28 g) in T_1.

It is evident from data that all the treatments significantly affected the fresh weight of shoots over T_1 (control). The maximum fresh weight of shoots (7.23 g) was recorded under treatment T_5 which was significantly superior over rest of the treatments and minimum fresh weight of shoots (3.37 g) was noted under treatment T_1 (control).

The various treatments also showed great influence on dry weight of shoots over T_1 (control) at 150 days after sowing. The maximum dry weight of shoot (1.87 g) was recorded under treatment T_5 which was found to be significantly superior over rest of the treatments and minimum dry weight of shoot (0.92 g) was noted in treatment T_1.

Increase in fresh weight of roots is due to the influence of GA_3 on different plant parts, which could be due to its effect in stimulating cell division, cell elongation, auxin metabolism, cell wall plasticity and permeability of cell membrane leading to enhanced growth. Increase in the dry weight of different plant parts due to improved mobilization of nutrients due to the application of GA_3, which promotes plant growth and development. The findings are agreement with the findings of Rahemi and Baninasab (2000). A part from that at 400 ppm maximum polyembryony is observed which gives rise to maximum biomass per plant. This result is in agreement with the findings of Hore and Sen (1995) in which he reported that at 400 ppm maximum polyembryony is found in acid lime. Plant growth regulators and some chemicals are widely used in increasing fresh and dry weight of root or shoot. Similar findings were reported by Parmar et al. (2016).

Table 1. Effect of seed treatment on Days taken to start germination, Days taken to 50% germination and germination percentage at 60 (DAS).

Treatments		**Days taken to start germination**	**Days taken to 50% germination**	**Percentage of germination at 60 DAS**
Control	T_1	38.00	45.13	64.41
Water soaking	T_2	33.80	40.67	70.00
GA_3 -200 ppm	T_3	31.67	38.53	78.33
GA_3 -300 ppm	T_4	31.40	38.47	80.00
GA_3 -400 ppm	T_5	29.73	37.40	86.67
Thiourea -0.5 %	T_6	31.87	38.60	77.07
Thiourea -0.75 %	T_7	32.13	38.67	76.67
Thiourea -1.00 %	T_8	32.53	38.80	72.19
KNO_3 -0.5 %	T_9	32.27	38.73	73.33
KNO_3 -0.75 %	T_{10}	31.13	37.93	83.33
KNO_3-1.00 %	T_{11}	30.47	37.60	85.00
Sodium Thiosulphate -150 ppm	T_{12}	31.33	38.40	81.67
Sodium Thiosulphate -200 ppm	T_{13}	32.87	39.07	71.67
Sodium Thiosulphate-250 ppm	T_{14}	33.13	39.87	71.08
S.Em ±		1.07	0.85	4.29
C.D 5% level		3.11	2.48	12.48

Table 2. Effect of seed treatment on length of shoots (cm)

Treatments		**Length of shoots (cm)**			
		60 DAS	**90 DAS**	**120 DAS**	**150 DAS**
Control	T_1	4.67	10.57	15.99	22.77
Water soaking	T_2	4.94	10.67	16.18	25.17
GA_3 -200 ppm	T_3	5.57	11.73	18.74	29.72
GA_3 -300 ppm	T_4	5.79	11.90	18.89	30.21
GA_3 -400 ppm	T_5	6.54	14.99	23.64	38.49
Thiourea -0.5 %	T_6	5.55	11.65	18.46	29.60
Thiourea -0.75 %	T_7	5.54	11.61	18.29	29.57
Thiourea -1.00 %	T_8	5.47	11.40	17.69	28.18
KNO_3 -0.5 %	T_9	5.51	11.42	18.00	28.31
KNO_3 -0.75 %	T_{10}	5.92	12.15	19.69	31.31
KNO_3-1.00 %)	T_{11}	5.97	12.61	20.39	32.07
Sodium Thiosulphate -150 ppm	T_{12}	5.89	12.14	19.65	30.37
Sodium Thiosulphate -200 ppm	T_{13}	5.19	11.39	16.91	28.09
Sodium Thiosulphate-250 ppm	T_{14}	5.14	10.70	16.72	26.04
S.Em ±		0.26	0.41	0.90	1.01
C.D 5% level		0.76	1.20	2.61	2.95

Table 3. Effect of seed treatment on girth of stem (mm)

Treatments		**Girth of stem (mm)**			
		60 DAS	**90 DAS**	**120 DAS**	**150 DAS**
Control	T_1	1.19	1.60	2.77	3.10
Water soaking	T_2	1.24	1.70	2.84	3.20
GA_3 -200 ppm	T_3	1.49	2.20	3.08	3.53

GA_3 -300 ppm	T_4	1.52	2.22	3.09	3.67
GA_3 -400 ppm	T_5	1.79	2.52	3.17	4.08
Thiourea -0.5 %	T_6	1.48	2.15	2.99	3.47
Thiourea -0.75 %	T_7	1.47	2.13	2.97	3.40
Thiourea -1.00 %	T_8	1.38	2.00	2.90	3.34
KNO_3 -0.5 %	T_9	1.45	2.03	2.95	3.37
KNO_3 -0.75 %	T_{10}	1.58	2.27	3.12	3.78
KNO_3-1.00 %	T_{11}	1.69	2.28	3.13	3.88
Sodium Thiosulphate -150 ppm	T_{12}	1.54	2.25	3.10	3.70
Sodium Thiosulphate -200 ppm	T_{13}	1.36	1.99	2.87	3.31
Sodium Thiosulphate-250 ppm	T_{14}	1.26	1.85	2.86	3.26
S.Em ±		0.10	0.14	0.04	0.10
C.D 5% level		0.28	0.40	0.13	0.28

Table 4. Effect of seed treatment on number of leaves per seedling

Treatments		**Number of leaves per seedling**			
		60 DAS	**90 DAS**	**120 DAS**	**150 DAS**
Control	T_1	5.27	9.53	16.30	22.33
Water soaking	T_2	5.70	9.70	17.60	25.17
GA_3 -200 ppm	T_3	6.57	10.87	21.70	30.40
GA_3 -300 ppm	T_4	6.63	11.63	21.50	31.47
GA_3 -400 ppm	T_5	7.63	14.50	27.13	38.57
Thiourea -0.5 %	T_6	6.50	10.80	20.73	30.27
Thiourea -0.75 %	T_7	6.37	10.67	20.67	29.73
Thiourea -1.00 %	T_8	6.27	10.43	18.07	27.13
KNO_3 -0.5 %	T_9	6.30	10.47	20.40	29.00
KNO_3 -0.75 %	T_{10}	6.83	12.53	22.93	32.27
KNO_3-1.00 %	T_{11}	6.87	13.00	24.37	32.67
Sodium Thiosulphate -150 ppm	T_{12}	6.73	11.77	22.57	32.13
Sodium Thiosulphate -200 ppm	T_{13}	6.07	10.37	17.93	27.07
Sodium Thiosulphate-250 ppm	T_{14}	6.00	10.30	17.80	25.40
S.Em ±		0.18	0.36	1.05	1.07
C.D 5% level		0.51	1.04	3.05	3.11

Table 5. Effect of seed treatment on fresh weight of roots (g), Dry weight of roots (g), fresh weight of shoots (g) and Dry weight of shoots (g) at 150 days after sowing

Treatments		**Fresh weight of roots (g)**	**Dry weight of roots (g)**	**Fresh weight of shoots (g)**	**Dry weight of shoots (g)**
Control	T_1	1.09	0.28	3.37	0.92
Water soaking	T_2	1.13	0.32	4.06	0.95
GA_3 -200 ppm	T_3	1.46	0.49	4.63	1.16
GA_3 -300 ppm	T_4	1.48	0.51	4.70	1.17
GA_3 -400 ppm	T_5	1.92	0.66	7.23	1.87
Thiourea -0.5 %	T_6	1.41	0.42	4.58	1.15
Thiourea -0.75 %	T_7	1.34	0.38	4.56	1.14
Thiourea -1.00 %	T_8	1.30	0.35	4.54	1.05
KNO_3 -0.5 %	T_9	1.31	0.37	4.42	1.11

KNO_3 -0.75 %	T_{10}	1.60	0.56	4.85	1.20
KNO_3-1.00 %	T_{11}	1.75	0.59	4.91	1.23
Sodium Thiosulphate -150 ppm	T_{12}	1.53	0.52	4.80	1.19
Sodium Thiosulphate -200 ppm	T_{13}	1.29	0.34	4.29	1.03
Sodium Thiosulphate-250 ppm	T_{14}	1.20	0.33	4.09	1.00
S.Em ±		0.08	0.05	0.14	0.06
C.D 5% level		0.23	0.14	0.41	0.19

Table 6. Effect of seed treatment on Length of seedling (cm), length of root (cm), number of roots per seedling and survival percentage of seedlings at 150 days after sowing.

Treatments		**Length of seedling (cm)**	**Length of root (cm)**	**No. of roots per seedling**	**Survival percentage**
Control	T_1	38.92	16.15	31.27	66.67
Water soaking	T_2	42.78	17.61	35.27	70.67
GA_3 -200 ppm	T_3	49.66	19.94	39.80	78.00
GA_3 -300 ppm	T_4	50.86	20.65	41.13	76.00
GA_3 -400 ppm	T_5	61.63	23.14	48.70	86.67
Thiourea -0.5 %	T_6	49.57	19.64	39.47	71.33
Thiourea -0.75 %	T_7	48.99	19.41	39.33	87.67
Thiourea -1.00 %	T_8	46.75	18.57	38.07	73.33
KNO_3 -0.5 %	T_9	47.49	19.11	38.87	77.33
KNO_3 -0.75 %	T_{10}	53.07	21.43	45.73	80.00
KNO_3-1.00 %	T_{11}	53.51	21.44	46.47	83.33
Sodium Thiosulphate -150 ppm	T_{12}	51.08	20.71	43.80	74.00
Sodium Thiosulphate -200 ppm	T_{13}	46.41	18.32	37.53	72.67
Sodium Thiosulphate-250 ppm	T_{14}	44.31	17.93	37.13	74.67
S.Em ±		1.44	1.01	3.06	2.58
C.D 5% level		4.17	2.93	8.90	7.51

Survival percentage of seedlings

The data revealed that various treatments have great influence on survival percentage of seedling over T_1 (control) at 150 DAS. Data indicates that maximum survival percentage (87.67) was recorded under T_7 which was found statistically at par with T_5 (86.67) and T_{11} (83.33) whereas minimum survival percentage of (66.67) under T_1 (without water soaking) at 150 days after sowing. The finding was supported by Meena et al. (2003). Survival percentage in aonla 100 days old seedlings were significantly highest in the 1% KNO3 treatment. The finding was supported by Purbey and Meghwal (2005).

CONCLUSION

Based on the present investigation, it is concluded that GA_3, concentration at 400 ppm (T_5) was proved superior in respect to germination of custard apple seed as well as growth parameter and survival of custard apple seedling.

Application of research

The findings are useful to custard apple growers and as well as for other crop.

Research Category

Horticulture

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RESEARCH ARTICLE

MANAGEMENT OF SOIL SYSTEM USING PRECISION AGRICULTURE TECHNOLOGY

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Abstract: To maximize the productivity from the limited natural resources on a sustainable manner, the only way left is to increase the resource input use efficiency. It is also certain that even in developing countries, availability of labour for agricultural activities is going to be in short supply in future. The time has now arrived to exploit all the modern tools available by bringing information technology and agricultural science together for improved economic and environmentally sustainable crop production. In this context, Precision agriculture merges the new technologies borne of the information age with a mature agricultural industry. It is an integrated crop management system that attempts to match the kind and amount of inputs with the actual crop needs for small areas within a farm field. This goal is not new, but new technologies now available, allow the concept of precision agriculture to be realized in a practical production setting.

Keywords: Management, Precision agriculture, Soil system

INTRODUCTION

Agriculture production system is an outcome of a complex interaction of seed, soil, water and agro-chemicals (including fertilizers). Therefore, judicious management of all the inputs is very essential to be taken care by the growers. However, since long, it has been recognized that crops and soils are not uniform within a given field. To meet the forthcoming demand and challenge we have to divert towards new technologies, for revolutionizing our agricultural productivity through judicious management of all the inputs and it is the key point for the sustainability of such a complex system. Therefore, it is essential to develop eco-friendly technologies for maintaining crop productivity. This concern brings the scientific community to make precise application of all the inputs in a given land area rather increasing the land area which is already a permanent constraint. Precision management is the proper use of high-technology equipment and software to quantify field conditions and micromanaging the elements or resources at small or large land areas to obtain optimum benefits. It requires an understanding of time and space scales. Time scales are critical because operations occur when they will benefit the crop most. Space scales become a fundamental principle of field management because inputs and cultural practices are varied with soil type, pest population, or crop maturity. The challenge is to determine how to use time and space scales to advantage in developing an improved understanding of agricultural management. To fully achieve the goals of precision agriculture, management must be applied in a space and time context.

The goals of precision management are actually quite clear. The first and foremost goal of the farmers is searching for higher yields and/or higher profits. Income provides the family needs, enhances the community, and keeps the farming operation viable. Reducing inputs normally results in lower input costs and lower impacts on air, land and water. Also, our society expects farmers to be natural resource managers and good stewards of the environment.

The goals of agriculturists-cum-natural resource manager should be:

A: Higher Yields and/or more profit
B: Reduced inputs and/or cost
And
A: To minimize environmental impacts
B: To preserve recreational enjoyment for future generations

Elements of Precision Agriculture: Precision farming basically depends on measurement and understanding of variability, the main components of precision farming system must address the variability. Precision farming technology is information based and decision focused, the components include, (the enabling technologies):

Global positioning system (GPS)
Remote sensing
Geographic information system (GIS)
Analysis/decision software
Variable rate technologies (VRT)
Electronics and instrumentation (yield monitors, soil sensors etc.)

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Soil variability

Amongst the various catalysts, Soil is a spatial variable, initially to cover most of risks while growing. The vigorousness of any plants depends largely on its inner potential and on prevailing ambient conditions in soil for the plant to take a good start. Water-holding capacity or organic matter variation, along with topography, provides even a more interesting view of a field in which a producer places inputs or disturbs the soil. Other variables could be identified within this field to create a series of interacting elements. Among them topographic variation within fields can be collected from topographic maps, but the resolution on these maps is often insufficient to provide the necessary detail about variations within fields. For this, the detailed summary of soil sampling and interpolation techniques that potentially could be used to quantify soil variation. This technology defines these sampling methods as judgmental sampling, simple random sampling, stratified sampling, cluster sampling, nested or multistage sampling, systematic sampling, stratified systematic unaligned sampling, and search sampling. None of these methods are described herein, but all have been used to determine variability across a field.

The technology which affords the following objectives:

1. It allows for the application of fertilizers at variable rates according to variations in fertility levels.
2. It allows for the measurement of yield variability in fields.
3. It helps to increase yields by reducing variability.
4. It allows for soil sample sites to be accurately located within a field and fertility levels mapped.
5. It allows for the monitoring of yield as compared to soil test results.
6. It accurately pinpoints accurately location of significant soil variability.

Management of Soil Using Precision Agriculture Technology:

Soil is a major component of a sustainable agricultural system. Soil quality is the capacity of a soil to function in a productive and sustained manner, while maintaining or improving the resource base, environment, and plant, animal, and human health. The capability of a soil to function within ecosystem boundaries and interact with the environment, external to that system forms the basis for determining the potential impact of soil management systems on the environment. Thus, the measurement of soil quality should be a quantitative tool to help guide management decisions. Among the various measuring parameters, nutrient balancing of soil is one of the key approaches to presume a good input return. Thus, to make it possible, soil sampling assumes much greater significance when Precision or Site-specific Farming is adopted, because of the precision and representation required the variable rates of nutrient calculation and application, and the economics of the technology as a whole. Therefore, the following factors should be considered while sampling to estimate the nutrient status of soil:

Purpose

The purpose of soil sampling should be clearly determined prior to beginning a detailed sampling of the area. If one or more of the components of Precision Farming Technology is not available, a traditional sampling and testing approach will probably provide just as much useful data, thus saving the time and money spent on developing a detailed sampling strategy.

Resolution

The high resolution obtained through a high intensity of samples from a given area may not always translate into useful and practical information. The optimum number of samples required from a particular field is often determined from the historical logs and experience of high- and low-yielding areas, areas with identifiable features like depressions, etc.

Data Analyses

The data generated from the soil tests should be analyzed and interpreted with appropriate perspective that will reflect the site, cropping sequence, and resources available on the farm.

Soil Properties

Soil samples can be obtained to analyze for both physical and chemical properties. A baseline on soil physical properties, like textural analysis, bulk density, permeability, hardpans, and depth to clay, can be obtained through a onetime assessment. Unlike soil chemical tests it is not necessary to repeat a physical property test unless a soil amendment is added to ameliorate soil physical conditions like bulk density and hardpan. Field-scale alterations to physical properties like soil texture and depth to clay is not possible. Soil chemical properties include soil pH and extractable plant nutrient levels. Soil testing is recommended every season/year when Precision Technology is adopted for documenting improvements in soil pH and soil fertility levels.

Fertilizer recommendation

The key part of soil sampling and analyses is the fertilizer recommendation that accompanies each soil test report. This forms the basis for all the remaining activities involving inputs into the production cycle. Therefore, it is important to adhere to the rates of nutrients recommended. Altering the recommended rates on soil test reports for the sake of convenience will totally negate the benefits and may result in poor crop performance and economic losses.

Soil Sampling Techniques

Based on the shape and size of individual fields within a farm where crops are to be planted, suitable sampling schemes can be identified:

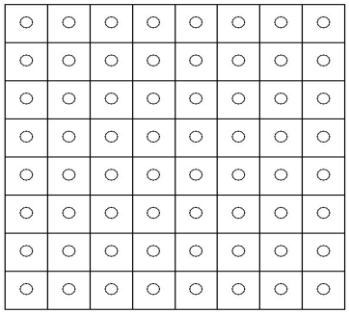

Fig. 1. Grid centred soil sampling.

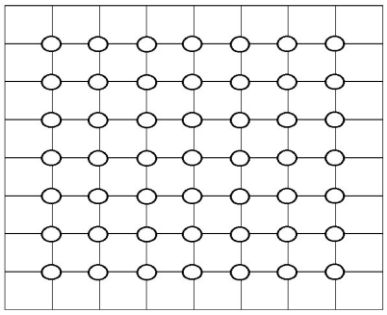

Fig. 2. Random sampling within grids.

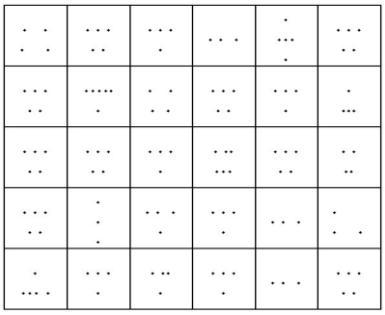

Fig. 3. Sampling at the grid intersections

Grid Sampling

A checkerboard-type grid can be created using special software such as SST Toolbox etc. The grid approach works best when large tracts of land are available. While these shapes and sizes can be adjusted to suit the need and convenience, the most popular grid sizes used are of 2-acre grids. Even one-acre grids are used on areas where a need for intensive sampling is identified. These fixed-area grids will therefore divide the field into equal square-shaped areas from within which samples will be collected. These square shaped areas are also referred to as 'cells'. There are at least three methods of sample collection within a grid that are practical. (1) One method is to go to the centre of the grid with the GPS unit and walk several steps away from the centre in all directions to collect samples from 3-5 spots randomly and consolidate them (Fig. 1).Being relatively simple, this grid-centred approach can be consistently done on any given field. However, for unbiased sampling, care should be taken to avoid concentration of samples around the centre point. (2) The second method is to collect samples at random from all across the grid without any bearing on the grid-centre (Fig 2) The sampling pattern will not be consistent across the cells but this approach will ensure a better randomization. This procedure may be more time consuming because various sampling points have to be individually accessed across the grid area. (3) The third method of grid sampling is to collect samples at grid line intersections (Fig 3). This approach will mathematically integrate the values (interpolate) between the points, which will enable creating contour maps based on the soil nutrient levels. The smaller the grid area, chosen, the higher the sampling intensity thus is increasing the costs.

Directed Sampling

A self-directed sampling is another scheme that is often adopted. This method requires a prior knowledge of the site characteristics that may be limiting the yield. Once these low/high yielding areas, soil types, areas under different cultural management, cropping systems, etc. are identified within a field, maps would be created to delineate the field accordingly and sampling would be conducted within these sub-regions. However, sampling based on factors that do not influence the yield should be avoided. This will effectively reduce the total number of samples.

In order to obtain optimum returns, a *Directed Sampling* scheme developed in conjunction with a good assessment of available resources and the ability to apply nutrients at variable rates is highly recommended. Assessment will be most useful by considering the maximum area or *Management Unit* across which a fertilizer rate cannot be varied. A Management Unit will be a subunit of the entire field under consideration and representative samples should be randomly collected and composited for analysis. The results will then be averaged across this area and applications will be made based on averages derived for this unit. Variations, if any, will be made among different units but not within any given unit. This process would be the most effective and economical of all.

Management of Collected Soil Data

As the soil samples have been collected as per latitude, longitude and altitude basis via. using grid or direct samplings, the samples can be processed to go under different nutritional analysis. The chemical analyses of the samples provide the nutritional inventory of the selected area. The prepared tabulated data can further be used to manage the field variability using variable rate technology (VRT).The VRT is the most advanced component of precision farming technologies, provides "on-the-fly" delivery of field inputs. There are two methods to use this VRT technology in management of nutrient unbalancing. The first method, in which, different maps are prepared using different thematic layers using Arc view 3.2a GIS software. This method includes the following steps: grid sampling of a field, performing laboratory analyses of the soil samples, generating a site-specific map of the properties and finally using this map to control a variable-rate applicator. During the sampling and application steps, a positioning system, usually DGPS (Differential Global Positioning System) is used to identify the current location in the field. The second method, Sensor-based, utilizes real-time sensors and feedback control to measure the desired properties on-the-go, usually soil properties or crop characteristics, and immediately use this signal to control the variable-rate applicator.

Sensor Technology in Soil

Intensive grid sampling is generally regarded as one of the most accurate methods of mapping the variability of crop and soil attributes in precision agriculture. However, intensive grid sampling is laborious, time consuming and expensive and thus impractical for implementation in large scale. It is, therefore, desirable to develop a more rapid means of obtaining spatial and temporal data for detailed variability mapping. The efficiency of site and time-specific crop-soil management and monitoring strategies can be improved by using low-cost sensors to estimate soil properties that impact crop yields. On-the-go soil sensor technologies that can serve as a rapid method for measuring soil mechanical, physical and chemical properties are steadily developing.

In present Scenario, various sensors have been developed to quantify the soil properties, required for accurate mapping within-field variability as per requirement. These sensor devices are fitted with a global positioning system (GPS) to allow for soil data to be captured on-the-go and instantaneously converted into distribution maps. This would facilitate real time monitoring and intervention of soil nutrient status, which can potentially offset limitations imposed by the inherent spatial and temporal variability in soil nutrient supply. Soil sensors can be used to generate real-time soil data, such as pH, electrical conductivity, salinity, dissolved oxygen and nutrient concentration, which are subsequently turned into geo-referenced maps to facilitate site-specific nutrient application. Numerous on-the-go sensors have been manufactured (Table 1) to measure mechanical, physical and chemical soil properties and most of them have been based on electrical and electromagnetic, optical and radiometric, mechanical, acoustic, pneumatic and electrochemical measurement concepts.

Table 1. The various types of soil sensor and their applications in the study of soil

Sensor type	Example applications	Reference
Electrochemical	Soil pH, Nitrate, Potassium	Adamchuk *et al.* (2007;2004)
Electrical and electromagnetic	Soil texture, Soil Moisture content, Soil depth variability (depth of topsoil, depth to hardpan), cation exchange capacity	Kim *et al*. (2009); King *et al*. (2005): Sudduth *et al*. (2003)
Optical and radiometric	Soil organic matter, Soil moisture	Rossel *et al*. (2006); Chang *et al*. (2001)
Acoustic	Soil texture, Soil bulk density, Soil depth variability	Grift *et al*. (2002)
Mechanical	Soil compaction, compacted soil layers	Stafford and Werner (2003); Manor and Clark (2001)

Generally, the main concerns in sensor performance efficiency are the issues of precision and accuracy. Precision refers to the ability of the sensor to repeat its own measurement in the same location and time, while accuracy refers to how well the sensor measurements correlate to an actual soil property that is determined using the conventional measurement technique.

Limitations of Precision Technology in Indian Context:

Although precision farming is proven technology in many advanced countries of the world but their scopes in India (also in other developing countries) are limited. Different scientists have reported certain constraints, which limited the scope for site-specific farming in India, are as given follows:

1. Small farms size and heterogeneity of cropping systems.
2. Lack of local technical expertise.
3. Infrastructure and institutional constraints including market uncertainty.
4. High initial investment.
5. Data availability and technical gaps
6. Complexity of tools and techniques requiring new skills.
7. Culture, attitude and perceptions of farmers including resistance to adoption of new techniques and lack of awareness of agro-environmental problems.
8. Uncertainty about the returns from investments on new equipment.

CONCLUSION

Precision agriculture in today's agriculture is being proven as a pavement in enhancing agricultural productivity without jeopardizing the ecological balance. This technology gives farmers the ability to use crop inputs more effectively including fertilizer, pesticides, tillage and irrigation water. More effective use of inputs means greater crop yield and/or quality, without polluting the environment. This technology also cuts an extravagant investment on required inputs which is a prime importance of a farmer to look upon. But, the technology is mainly prevalent in the developed countries. India is still to take revolutionary step in precision agriculture but the basic issues which hurdles this technology to flourish in Indian context are: fragmented land holdings, heterogeneity of crops and livestock and concept of farm families in the rural conditions etc.

The on-the-go sensors have the advantage of providing non-destructive and rapid quantification of soil variability to enable precision soil nutrient management and monitoring. However, the reliability of the data taken about crop-soil properties by the on-the-go sensor under different growing condition is still unclear. But, the increasing population in association to climate change requires a commensurate increase in agricultural productivity. Key to this challenging task is to ensure sustainable soil productivity while maintaining high crop yields and reducing environment pollution. Thus, to recover from all these factors, a sensor technology for nutrient management is a good way to achieve such goals.

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RESEARCH ARTICLE

FINE ROOT BIOMASS AND SOIL PHYSICO-CHEMICAL PROPERTIES IN ACHANAKMAR-AMARKANTAK BIOSPHERE RESERVE

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Abstract: The present study was aimed to assess the fine root biomass and soil physico-chemical properties in Achanakmar-Amarkantak Biosphere Reserve. Four sites characterized by varying vegetation attribute and representative of the region were selected. The belowground plant material (stand fine roots < 5 mm diameter) was sampled from 10 monoliths (15 x 15 x 15 cm) on each site. Proportions of live and dead fine roots were estimated on the basis of visual observations such as colour, texture, etc. Sample were dried at 80^0C to constant weight and weighed. Fine root biomass varied between 0.95 - 3.85 t ha^{-1}, respectively Organic C in soil ranged from 0.62 - 2.1 %, total N from 0.06 - 0.18 % and total P from 0.029 - 0.037 %. Available Pi ranged from 0.0002 - 0.00028 %. The exchangeable K ranged between 0.025 - 0.288 %. The short-lived components of the ecosystem viz., foliage, herbs and fine roots play a significant and dominant role in the functioning (relative contribution to nutrient cycling) of the present tropical deciduous forest.

Keywords: Fine root biomass, Nutrient cycling, Physico-chemical properties, Soil sample, Tropical deciduous forest

INTRODUCTION

Fine root biomass in tropical forest ecosystem plays a vital role in carbon and nutrient dynamics which alters the vegetational diversity, standing biomass and subsequently the productivity of an ecosystem (Yadav et al. 2017; Jordan, 1983). The transformation of forest landscape into various forms for other land-uses leads to severe degradation of such ecosystems which causes the biodiversity loss (Yadav et al. 2017; Jhariya and Yadav, 2018). Tropical forests possess rich floral and faunal diversity which highlighted the conservation and management priority of these valuable ecosystems for sustainable development (Sahu et al. 2008; Jhariya et al. 2019). In Indian context, the protected forests are under severe threats due to various anthropogenic processes which alter the structure and function of these ecosystems (Pawar et al. 2012 and 2014; Jhariya, 2014). From the study by Kaul and Sharma (1971), majority of Indian forests represent tropical (86%) both dry deciduous and moist deciduous in nature and nearly 14% of forest comprises wet evergreen or semi evergreen.

Fine roots play a key role in regulating the biogeochemical cycles of ecosystems and are important to our understanding of ecosystem responses to global climate changes (Yuan and Chen, 2010). Further it supports and performs various physiological functions in soil systems which facilitate soil solution uptake into the plant systems (Wells and Eissenstat, 2001). Fine root biomass adds little share in the total biomass input but have substantial importance due to its role in soil nutrients and carbon pool (Norby and Jackson, 2000; Sahu et al. 2013). There is less information is available related to fine root biomass and soil attributed at different forest stand level in Achanakmar-Amarkantak Biosphere reserve (Chhattisgarh). Therefore, the present investigation was carried out to study the fine root biomass and soil physico-chemical properties in Achanakmar-Amarkantak Biosphere Reserve (C.G.), India.

MATERIALS AND METHODS

The present study was carried out at Achanakmar-Amarkantak Biosphere Reserve. The study sites are located in 22º15'-22º58' N latitude and 81º25'-82º 5' E longitude having an area of 3835.51 km^2. Climate is tropical and is influenced by monsoon conditions. The mean monthly temperature varies from 17.2^0C (January) to 31.8^0C (May) and the total annual rainfall average 1383 mm, of which 85 % occurs in the rainy season (Yadav, 2016, 2018). The soils of the area are generally lateritic, alluvial and black cotton type, derived from granite, gneisses and basalts. The forest is seasonally dry tropical and includes extensive tracts of old growth *Shorea robusta* forest. Forest is classified into Northern Tropical Moist Deciduous and Southern Dry Mixed Deciduous forests (Champion and Seth, 1968). The former type predominates in the Biosphere Reserve area.

Four sites (Dense, Medium, Regenerating and Degraded) characterized by varying vegetation attributes and representative of the region's vegetation were selected. The belowground plant material (stand fine roots < 5 mm diameter) was sampled from 10 monoliths (15 x 15 x 15 cm) on each site. Monoliths were washed with a fine jet of water using 2 mm and 0.5 mm mesh screens (Bohm, 1979). Proportions of live and dead fine roots were

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estimated on the basis of visual observations such as colour, texture, etc. Sample were dried at 80^0C to constant weight and weighed. Fine roots were classified into two classes: fine roots < 1 mm diameter and (2) fine roots > 1 - 5 mm diameter. Finally each fine root class was converted into live fine roots and dead fine roots using live and dead fine roots proportions.

Soil samples were collected randomly from 5 locations on each site from the upper 10 cm depth. The samples were mixed thoroughly and large pieces of plant material were handpicked. Soils were sieved through a 2 mm mesh screen. Samples were divided in two parts, one part was air dried while the other was kept field-moist. Field-moist samples were used for the analysis of P. Rest of the analysis was carried out on air dried soil. Particle size distribution (texture) was analysed by using pipette method (Piper, 1950). Bulk density was determined by measuring the weight of dry soil of a unit volume to a depth 10 cm. Water holding capacity (WHC) was determined using perforated circular brass boxes (Piper, 1950). Total soil N and organic-C were analysed by CHNOS-Auto Analyzer "Elementar Vario EL. $NaHCO_3$ – extractable Pi was determined by ammonium molybdate-stannous chloride method (Sparling et al., 1985). Total soil phosphorus (TSP) was determined after $HC1O_4$ digestion of air dried soil (Jackson, 1958). All data are expressed on oven dry weight basis (105^0C, 24 hr).

RESULTS AND DISCUSSION

Fine Root Biomass

Dense forest

The fine root biomass measured on different site and season given in Table 1 and Table 2. The maximum fine root biomass occurred in October (end of the rainy season) and minimum in July (the beginning of the rainy season). Total fine root biomass, averaged for all sampling intervals, was 3.85 t ha^{-1} (Table 1) and ranged seasonally from 3.15 t ha^{-1} (summer) to 4.29 t ha^{-1} (rainy season), (Table 2). Bulk of the fine root biomass belonged to < 1 mm diameter class (84 % of the total). In this diameter class live roots averaged 79 % and dead roots 21 %. However, in > 1 - 5 mm diameter size, live roots accounted for upto 93 % biomass. In an annual cycle proportion of dead fine roots was maximum (29 %) in June and minimum (11 %) in August.

Regenerated forest

Data on fine root biomass are included in Appendix Table 3.The maximum fine root biomass occurred in September and minimum in April. Total fine root biomass, averaged for all sampling intervals, was 2.75 t ha^{-1} (Table 1) and ranged seasonally from 2.02 t ha^{-1} (summer) to 3.36 t ha^{-1} (rainy season) (Table 2). Bulk of the fine root biomass belonged to < 1 mm diameter class (85 % of the total). In this diameter class live roots averaged 81 % and dead roots 19 %. However, in > 1 - 5 mm diameter size, live roots accounted for upto 85 % biomass. In an annual cycle proportion of dead fine roots was maximum (25 %) in April and minimum (13 %) in February.

Medium forest

The fine root biomass measured on different sampling dates is given in Appendix Table 3. The maximum fine root biomass occurred in September and minimum in July. Total fine root biomass, averaged for all sampling intervals, was 3.48 t ha^{-1} (Table 1) and ranged seasonally from 2.89 t ha^{-1} (summer) to 3.78 t ha^{-1} (rainy season), (Table 2). Bulk of the fine root biomass belonged to < 1 mm diameter class (83 % of the total). In this diameter class live roots averaged 78 % and dead roots 22 %. However, in > 1 - 5 mm diameter size, live roots accounted for upto 96 % biomass. In an annual cycle proportion of dead fine roots was maximum (32 %) in April and minimum (12 %) in August.

Degraded forest

The maximum fine root biomass occurred in September and minimum in December and April. Total fine root biomass, averaged for all sampling intervals, was 0.95 t ha^{-1} (Table 1) and ranged seasonally from 0.72 t ha^{-1} (summer) to 1.10 t ha^{-1} (rainy season), (Table 2). Bulk of the fine root biomass belonged to < 1 mm diameter class (77 % of the total). In this diameter class live roots averaged 80 % and dead roots 20 %. However, in > 1 - 5 mm diameter size, live roots accounted for upto 84 % biomass. In an annual cycle proportion of dead fine roots was maximum (25 %) in April and minimum (6 %) in September.

The fine root production and its decomposition in soil substratum are very much essential towards mineralization and nutrients cycling perspectives. The variation in the fine root biomass in different forests stand is found to be substantial in the total mass and by components in different season basis. The present finding was supported by Sahu et al. (2013) as they mentioned the total fine root biomass in the tropics of Chhattisgarh was ranged between 4.80-9.81 t ha^{-1}.

The mean fine root biomass in the boreal forest was 5.28 Mg ha^{-1}, and the production of fine roots was 2.82 Mg ha^{-1} yr^{-1}, accounting for 32% of annual net primary production of the boreal forest. Fine root biomass, production, and turnover rate generally increased with increasing mean annual temperature and precipitation (Yuan and Chen, 2010). The fine root biomass, production, turnover and nutrient pools have been found to be the results of internal factors as the genotype of plant species and several external factors such as soil properties, stand age, and climate (Vogt et al., 1986; Jackson et al., 1996; Vogt et al., 1996; Cairns et al., 1997; Joslin et al., 2000; Pregitzer et al., 2000; Leuschner and Hertel, 2003; Block et al., 2006; Kalyn and Van Rees, 2006; Brassard et al., 2009). However, it is still unclear how fine roots change over a large biome scale.

Physico-Chemical Characteristics of Soils

Tables 3 and 4 summarize the values for physico-chemical characteristics of the soil on different sites. Silt content was 28 %, 26 % , 29 % and 28 % while the clay content was 18 %, 13 % ,15 % and 4 % on dense, regenerated, medium and degraded forest sites, respectively, indicating maximum silt + clay content on dense and medium sites (44 %) and minimum on degraded site (32 %).Bulk density ranged between 1.33-1.56 g cm^{-3}**,** being maximum on degraded site and minimum on closed. The Water holding capacity was maximum on dense site (46 %) and minimum on degraded site (38 %).

Total soil N ranged from 0.06 - 0.18 % with the maximum on dense forest site and minimum on degraded forest site. Total soil P and mean annual $NaHCO_3$ - extractable Pi were least on degraded forest and highest on dense forest site and ranged between 0.029 - 0.037 % and 0.0002 - 0.00028 %, respectively. Soil organic C contents for dense, regenerated, medium and degraded forest sites were 2.1 %, 1.68 %, 1.67 % and 0.62 %, respectively. C:N ratio was highest on dense forest and least on medium forest and ranged from 9.8-11.67.

Total P: mean annual available pi ratio

The ratio was computed to assess the capacity of soil to release the available phosphate ions, which are readily absorbed in the exchange reaction between plant and solution. Wider ratio show a low releasing capacity and narrower ratio a high rate of release of the available fraction. In the present study the ratio ranged between 124 and 145 on different sites with the mean value being 132. Thus, the present study indicates a very low rate of release of the available fraction.

Exchangeable K

The value for exchangeable potassium ranged from 0.025 - 0.288 % in the present soils. Highest concentration of exchangeable K occurred on dense forest site.

Soil resource availability greatly impacts plant growth but its effects on fine roots are still unclear (Nadelhoffer, 2000). The findings of Janmahasatien and Phopinit (2001) were also supports the present value of soil attributed of different forest stand. Soil nutrient status and its associated dynamics are interrelated with climatic factors, site conditions, soil parental materials and weathering process, mineralization, soil properties and vegetation mix and its dynamics over the sites (Burke, 1989). Similar to present finding Sahu et al. (2013) reported total N ranged from 0.083 to 0.143% for 0-10 cm soil layer and 0.064 to 0.091% for lower layer soil (10-20 cm). The total C ranged from 1.124-1.736% for surface soil sample and 0.703 to 1.312% for lower layer soil sample. The concentration of available P (0-20 cm) under different sites varied from 8.55-15.72 kg ha^{-1} and 13.74-12.06 kg ha^{-1}. The results of available K for the soil were 249.54-382.21 kg ha^{-1} in different soil depths. Further, Chauhan et al. (2010) mentioned the 2.2% soil organic carbon for natural forest and 1.5% for planted stand whereas the available P ranged from 8.4-10.7 kg ha^{-1} for different sites. The N was 209.2 kg ha^{-1} for natural stand and 170 kg ha^{-1} for plantation site whereas K in available form 294.5-331 kg ha^{-1} for different sites. Tangsinmankong *et al.* (2007) revealed decreased pattern in the concentration of soil organic carbon in different sites with the increase in soil depth from upper horizon to lower layer soil.

Singh *et al*. (2000) revealed that temporal variation in soil organic carbon, increased soil organic carbon associated with fine root and litter biomass. Further, Singh and Singh (2002) mentioned that nutrient availability in soil was significantly higher under the tree canopy than the open forest area or non-planted sites.

Table 1. Mean live and dead fine root biomass on different forest sites (g m^{-2} ±1SE)

Components	Dense	Regenerated	Medium	Degraded
< 1mm live	254.75±26.64	190.00±20.09	225±21.41	64.38±8.10
< 1 mm dead	67.5±4.73	43.75±4.80	65.0±6.62	8.75±1.34
>1-5 mm live	58.25±10.73	35.25±3.88	56.25±7.55	18.12±2.30
> 1-5 mm dead	4.25±0.88	6.0±0.91	2.6±0.42	3.38±0.50
Total	384.75	275.00	348.85	94.63

Table 2. Seasonal pattern of fine root biomass on different forest sites (g m^{-2} ±1SE)

Seasons	Dense	Regenerated	Medium	Degraded
Rainy	429.5±54.11	335.5±55.55	377.75±65.08	110.25±15.04
Winter	364.5±55.51	227.5±32.37	350.0±50.26	86.00±8.79
Summer	315.5±35.43	201.5±32.70	289.5±47.24	72.00±8.89

Table 3. Physical properties of soil on different forest sites

Properties	Dense site	Regenerated site	Medium site	Degraded site
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Mechanical composition				
Sand (%)	54±2.6	61.0±4.4	56.0±6.2	68.0±6.2
Silt (%)	28.0±4.1	26.0±3.5	29.0±4.0	28.0±4.0
Clay (%)	18.0±2.1	13.0±2.3	15.0±0.6	4.0±0.6
Bulk density (g cm^{-3})	1.33±0.3	1.36±0.2	1.35±0.3	1.56±0.3
Water holding capacity (%)	46.0±8.7	44.0±7.0	45±9.2	38.0±9.5

Table 4. Chemical properties of soil on different forest sites

Properties	Dense site	Regenerated site	Medium site	Degraded site
Total N (%)	0.18±0.06	0.15±0.05	0.17±0.05	0.06±0.01
Total P (%)	0.037±0.004	0.031±0.005	0.033±0.0009	0.029±0.005
Available Pi* (PO_4-P) (%)	0.00028±0.00002	0.00025±0.00003	0.00026±0.00003	0.0002±0.00003
Organic carbon (%)	2.1±0.5	1.68±0.12	1.67±0.18	0.62±0.09
C/N ratio	11.67	11.2	9.8	10.30
C/P ratio	56.76	54.19	50.61	21.37
N/P ratio	4.9	4.84	5.2	2.06
Total P/available Pi	132.1	124	126.9	145
Exchangeable K (%)	0.288±0.008	0.228±0.05	0.249±0.007	0.025±0.005
Bulk density (g cm^{-3})	1.33±0.3	1.36±0.2	1.35±0.3	1.56±0.3

Note: (*) these analyses were carried out three times (rainy, summer and winter) in an annual cycle. The values in this table are averages of all seasons.

CONCLUSION

The study suggests that the high level of disturbance due to over exploitation of trees for timber and firewood had critically affected the fine root biomass and soil properties in the study area. This is evidenced by the very low density, diversity and basal area on degraded site. Litterfall and forest floor and fine root biomass are essential from the nutrient cycling perspective which leads toward healthy forest soil and its development. It is found that open forest and degraded forest stand were deficit in soil nutrient status and there availability. Therefore, appropriate management regime is required to protect the forest from subsequent degradation. To gain a better mechanistic understanding the controls of fine root dynamics, future studies shall emphasize decoupling the influences of individual environmental factors, tree species traits, and stand development on fine root dynamics. Further protections of regenerated and degraded site are prerequisite to regain the healthy vegetation cover and sustainable management.

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RESEARCH ARTICLE

YIELD AND ECONOMICS OF CROSSANDRA (*CROSSANDRA INFUNDIBULUFORMIS* L.) AS INFLUENCED BY NITROGEN AND POTASSIUM LEVELS

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Abstract: The results of the experiment indicated that, the application of nitrogen + potassium @ 150 kg + 60 kg followed by 100 kg + 120 kg significantly improved yield parameters (number of spikes per plant, spike length, number of florets per spike, floret length and flower yield per plant) and B: C ratio.

Keywords: B: C ratio, Crossandra, NK levels, Yield

INTRODUCTION

Crossandra (*Crossandra infundibuliformis* L.) is native of India. It is an important group of flowering plants cultivated on a commercial scale and is being grown extensively in South India. The cultivars with orange coloured flowers are generally preferred for commercial cultivation. The plants are quite hardy and can be grown for flowerbeds and /or for loose flowers. Chromosome number is 2n = 40. It is known as Kanakambara in Karnataka and Southern states of India. It does not have fragrant flowers but it is still desired for its distinct colour that has attracted the heart of every human being. It is an evergreen shrub of minor importance. It belongs to the family Acanthaceae. The family contains mainly herbaceous plants but also contains shrubs as well as few small trees. This is a large family of about 200 genera containing 2000 species. It consists of five cultivars, namely, orange, yellow, red, deep orange and bluish flowered forms. It is a sturdy, productive ornamental that should be more popular with indoor gardens. The bright orange coloured flowers are widely used in temple offerings and for making gajras and venis to use as hair adornments.

MATERIALS AND METHODS

A field experiment entitled 'Yield and economics of Crossandra (*crossandra infundibuluformis* L.) as influenced by nitrogen and potassium levels' was conducted at Horticultural College and Research Institute, Venkataramannagudem, West Godavari district, Andhrapradesh. The experiment comprising 16 treatment combinations consisted of four levels of nitrogen (0, 50, 100,150 Kg N/ha) and four levels of potash (0, 60, 120, 180 Kg K/ha) were tried in Factorial Randomized Block Design with three replications.

RESULTS AND DISCUSSION

Number of spikes per plant

Number of spikes per plant was found to increase with every increase in the nitrogen level up to 150 kg ha^{-1}. Supply of potassium could bring about an improvement in this parameter up to 60 kg ha^{-1} only. It is evident that better number of spikes per plant were recorded by nitrogen at 150 kg and potassium at 60 kg individually and also in combination. This combination could have encouraged the plant to put up more dry matter by increased photosynthetic surface or leaf area leading to better outturn of photosynthates which might have stimulated more floral buds and leading to a better number of spikes per plant. Similar results were reported by Dalvi *et al.* (2008) in gladiolus.

Spike length (cm)

The length of spike was found to show a significant increase with increase in the dose of nitrogen up to 150 kg ha^{-1} and potassium up to 60 kg ha^{-1} only. The combination of nitogen and potassium was found to be more efficient in bio-mass production with better availability of photosynthates. It is well established that nitrogen is one of the major essential elements, which regulates the cell or tissue functions of the plant being essential part of the nucleic acid, mitochondria and cytoplasmic contents of the cells. Nitrogen has a strong control on vegetative and reproductive stages of the plants. The role of potassium in plants includes cation transport across membrane, water economy, energy metabolism and enzyme activity. Potassium increases carbon exchange and enhances carbohydrate movement. The results are in confirmity with the findings of Patel *et al.* (2010), Lehri *et al.* (2011) in gladiolus.

Number of florets per spike

At higher nitrogen levels, more vegetative growth and more accumulation of food reserves are diverted to flower bud differentiation and resulted in more number of florets per spike. Elevated potassium level

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accelerated many bio-chemical reactions and led to the more number of florets per spike. The mechanism of flower bud initiation and development is closely related to the well flourished vegetative growth. The increased number of florets under higher dose of nitrogen may be attributed to more number of floret bearing branches per plant. Similar increase in flower number with higher fertilizer levels was also noticed by Saud and Ramachandra (2004) and Acharya and Dashera (2004) in marigold and Akkannavar (2001) in ageratum.

Floret length (cm)

Floret length was relatively better in higher doses of nitrogen and low dose of potassium since it had better nutrition and maintained sufficient reserves by recording a greater amount of dry matter production. The combination of nitrogen and potassium at 150 and 60 kg per hectare was found to produce more florets per spike which were better expanding and sustaining for a prolonged length of time. This nutrient combination showed an increase not only in flower size but also in spike length as evident from the present study. It is clear from these results that a satisfactory level of assimilates and their better partitioning into the reproductive parts could have brought about more floret number on longer spikes and also flowers could express fully in their size thus confirming the advantage of nutrient dose at the above combination. Plants could reach physiologically a better mature position where the strong vegetative frame work could enable them in sharing a better quantum of assimilates into reproductive organs thus improving their size in terms of floret diameter and length. These results are in concurrence with the findings of Baboo and Singh (2003) in marigold and Kumar *et al*. (2003) in china aster, Singh *et al.* (2008) in Asiatic hybrid lily.

Flower yield per plant (g)

The favourable growing environment and climatic factors will contribute for expression of maximum yield potential in the flowers. (Betonia, 1996, Praneetha *et al.*, 2002 and Talia *et al.* 2003).

Benefit - cost ratio

Benefit cost ratio is an important and ultimate factor which decides the optimum level of inputs to be used for maximization of production and returns in any crop. In the present study, the benefit-cost ratio was worked out for different levels of nitrogen and potassium fertilizers. By working out the economics of cultivation of crossandra under field conditions and by imposing these treatment combinations, it was observed that the major portion of cost of cultivation was due to planting material itself and the final cost of cultivation varied based on the treatment combinations comprising of different levels of nitrogen and potassium. The plants provided with nitrogen 150 kg ha^{-1} and potassium 60 kg ha^{-1} which produced maximum yield, gave maximum net returns per rupee invested thus recording a benefit cost ratio of 4.88 which could be attributed to the efficiency of these treatments in maximizing the returns. Similar findings were also reported by Manjula (2005), Qazi *et al.* (2005) and Nongthombam (2013) in gladiolus.

Table 1. Effect of different levels of nitrogen and potassium on number of spikes per plant in crossandra

Treatment	120 DAT					180 DAT				
	K_0	K_{60}	K_{120}	K_{180}	Mean	K_0	K_{60}	K_{120}	K_{180}	Mean
N_0	2.94	4.43	7.02	10.08	**6.12**	8.70	10.67	10.83	12.18	**10.59**
N_{50}	11.07	14.40	16.91	17.44	**14.95**	13.93	15.06	15.61	17.08	**18.42**
N_{100}	22.82	23.09	32.76	26.79	**25.58**	18.35	21.33	31.98	25.05	**30.94**
N_{150}	27.83	39.81	28.04	29.61	**32.11**	27.03	41.17	27.21	29.20	**36.39**
Mean	**17.39**	**21.29**	**19.64**	**20.43**		**17.54**	**22.09**	**19.63**	**22.07**	
Source	**N**	**K**		**N×K**			**N**	**K**		**N×K**
SE m±	0.26	0.26		0.32			0.49	0.49		0.98
CD at 5%	0.76	0.76		1.52			1.42	1.42		2.84

Table 2. Effect of different levels of nitrogen and potassium on spike length (cm) in crossandra

Treatment	120 DAT					180 DAT				
	K_0	K_{60}	K_{120}	K_{180}	Mean	K_0	K_{60}	K_{120}	K_{180}	Mean
N_0	3.84	4.35	4.51	4.60	**4.32**	7.34	7.54	7.61	7.63	**7.53**
N_{50}	4.63	4.74	4.08	4.80	**4.74**	7.90	8.01	7.96	8.15	**7.78**
N_{100}	4.90	5.16	5.59	5.30	**5.23**	8.18	8.22	8.49	8.23	**8.28**
N_{150}	5.39	5.81	5.41	5.40	**5.51**	8.26	8.67	8.34	8.39	**8.41**
Mean	**4.69**	**5.01**	**4.89**	**5.00**		**7.92**	**8.11**	**8.09**	**8.10**	
Source	**N**	**K**		**N×K**			**N**	**K**		**N×K**

SE m±	0.26	0.26	0.52	0.17	0.17	0.34
CD at 5%	NS	NS	NS	0.51	NS	NS

Table 3. Effect of different levels of nitrogen and potassium on number of florets per spike in crossandra

Treatment	**120 DAT**					**180 DAT**				
	K_0	**K_{60}**	**K_{120}**	**K_{180}**	**Mean**	**K_0**	**K_{60}**	**K_{120}**	**K_{180}**	**Mean**
N_0	20.02	44.11	97.24	151.65	**78.25**	161.32	175.51	205.40	226.27	**192.12**
N_{50}	172.70	244.92	283.81	286.74	**247.04**	231.47	243.00	290.30	291.85	**264.15**
N_{100}	362.04	418.35	562.01	473.44	**423.32**	369.59	422.73	573.36	486.45	**434.11**
N_{150}	439.45	576.29	521.82	493.74	**538.47**	457.67	581.27	544.72	510.10	**552.36**
Mean	**279.19**	**351.39**	**335.58**	**320.92**		**333.94**	**378.67**	**374.52**	**355.62**	
Source	**N**	**K**		**N×K**			**N**	**K**		**N×K**
SE m±	0.67	0.67		1.34			3.65	3.65		7.30
CD at 5%	1.95	1.95		3.90			10.54	10.54		21.18

Table 4. Effect of different levels of nitrogen and potassium on floret length (cm) in crossandra

Treatment	**120 DAT**					**180 DAT**				
	K_0	**K_{60}**	**K_{120}**	**K_{180}**	**Mean**	**K_0**	**K_{60}**	**K_{120}**	**K_{180}**	**Mean**
N_0	3.15	3.16	3.19	3.19	**3.17**	3.25	3.26	3.28	3.29	**3.23**
N_{50}	3.20	3.21	3.22	3.23	**3.21**	3.29	3.31	3.30	3.03	**3.27**
N_{100}	3.24	3.29	3.39	3.36	**3.32**	3.41	3.44	3.48	3.40	**3.43**
N_{150}	3.37	3.40	3.38	3.30	**3.38**	3.46	3.49	3.36	3.47	**3.44**
Mean	**3.24**	**3.29**	**3.26**	**3.27**		**3.35**	**3.37**	**3.35**	**3.29**	
Source	**N**	**K**		**N×K**			**N**	**K**		**N×K**
SE m±	0.03	0.03		0.06			0.04	0.04		0.08
CD at 5%	NS	NS		NS			NS	NS		NS

Table 5. Effect of different levels of nitrogen and potassium on flower yield per plant (g) in crossandra

Treatment	**120 DAT**					**180 DAT**				
	K_0	**K_{60}**	**K_{120}**	**K_{180}**	**Mean**	**K_0**	**K_{60}**	**K_{120}**	**K_{180}**	**Mean**
N_0	311.18	338.33	342.25	351.34	**335.77**	721.14	733.71	745.93	759.52	**740.07**
N_{50}	363.36	372.49	385.88	394.37	**379.02**	767.37	776.00	785.97	799.13	**782.11**
N_{100}	399.09	429.11	566.44	456.69	**462.83**	838.83	848.45	866.80	853.98	**852.05**
N_{150}	432.28	582.03	451.29	456.38	**480.49**	850.05	876.18	856.06	852.48	**858.69**
Mean	**335.77**	**436.46**	**430.49**	**414.69**		**794.34**	**816.27**	**813.69**	**808.58**	
Source	**N**	**K**		**N×K**			**N**	**K**		**N×K**
SE m±	0.70	0.70		1.40			0.32	0.32		0.64
CD at 5%	2.04	2.04		4.08			0.93	0.93		1.86

Table 6. Effect of different levels of nitrogen and potassium on economics of crossandra cultivation

Treatment combinations	**Additional cost (Rs)**	**Cost of cultivation (Rs)**	**Yield/hectare (kg)**	**Gross returns (Rs)**	**Net returns (Rs)**	**Benefit cost ratio**
N_0K_0	--------	2,12,488.00	2,239.00	8,95,600.00	6,83,112.00	3.21
N_0K_{60}	981.60	2,13,469.60	2326.00	9,30,400.00	7,16,930.40	3.35
N_0K_{120}	1,963.20	2,14,451.20	2347.00	9,38,800.00	7,24,348.80	3.37
N_0K_{180}	2,944.80	2,15,432.80	2413.00	9,65,200.00	7,49,767.20	3.48
$N_{50}K_0$	284.00	2,12,772.00	2456.00	9,82,400.00	7,69,628.00	3.61
$N_{50}K_{60}$	1,265.60	2,13,753.60	2478.00	9,91,200.00	7,77,446.40	3.63
$N_{50}K_{120}$	2,247.20	2,14,735.20	2543.00	10,17,200.00	8,02,464.80	3.73
$N_{50}K_{180}$	3,228.80	2,15,716.80	2586.00	10,34,400.00	8,18,683.20	3.79
$N_{100}K_0$	568.00	2,13,056.00	2673.00	10,69,200.00	8,56,144.00	4.01

$N_{100}K_{60}$	1,549.60	2,14,037.60	2760.00	11,04,000.00	8,89,962.40	4.15
$N_{100}K_{120}$	2,531.20	2,15,019.20	3108.00	12,43,200.00	10,28,180.80	4.78
$N_{100}K_{180}$	3,512.80	2,16,000.80	2847.00	11,38,800.00	9,22,799.20	4.27
$N_{150}K_{0}$	852.00	2,13,340.00	2782.00	11,12,800.00	8,99,460.00	4.21
$N_{150}K_{60}$	1,833.6	2,14,321.60	3152.00	12,60,800.00	10,46,478.40	**4.88**
$N_{150}K_{120}$	2,815.20	2,15,303.20	2826.00	11,30,400.00	9,15,096.80	4.25
$N_{150}K_{180}$	3,796.80	2,16,284.80	2827.00	11,30,800.00	9,14,515.20	4.22

Fertilizer cost = Urea – Rs 5 /kg; SSP – Rs 7/ kg; MOP – Rs 16/ kg Selling price of flowers: Rs 400 /Kg

CONCLUSION

Overall results indicate that the treatment combination of N_{150} P_{60} kg ha^{-1} is the optimum for the cultivation of crossandra under coastal Andhra Pradesh.

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RESEARCH ARTICLE

EFFECT OF POST EMERGENCE HERBICIDES ON GROWTH AND YIELD OF SOYBEAN

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Abstract: Soybean (*Glycine max* L. Merrill) is one of the commercial crops in India. It grown as *kharif* crop, but weed infestation is the major constraint in soybean produce in rainy season A field experiment was conducted at Research farm, Department of Agronomy, Jawaharlal Nehru Kirshi Vishwa Vidyalaya, Jabalpur (M.P.) during *kharif* 2016 to evaluate the bio-efficacy of post emergence herbicides against weed control in soybean. Among all herbicidal treatment the post emergence application of Imazethapyr+Propaquizafop 75.0+62.5 g/ha recorded highest number of pods/plant (26.10), higher number of seed/pod (2.40), 100 seed weight (9.93), seed yield (2100 kg/ha), haulm yield (3900 kg/ha), net returns (26585 Rs/ha) and B:C ratio (1.75), which was comparable with the application of Imazethapyr + Bentazone 75+75 g/ha.

Keywords: Herbicide, Benefit cost ratio, Net return, Weed control efficiency

INTRODUCTION

Soybean (*Glycine max* L. Merrill) is one of the commercial crops in India. It is called "Golden Bean" or "Miracle crop" of the 21st century because of its multiple uses, which contains 35-40% protein, 19% oil, 35% carbohydrate, 5% minerals and several other components including vitamins. The quality of soya protein is equivalent to that of animal protein and is also a good source of dietary fibre, calcium, magnesium, phosphate, thiamine, riboflavin, niacin etc. It has been reported to have in India it is grown under 11.65 million hectares area with the production of 8.0 million tonnes. In Madhya Pradesh it is cultivated under 5.9 million hectare area with production of 4.5 million tonnes (SOPA, 2016).

In the state it grown as *kharif* crop, but weed infestation is the major constraint in soybean produce in rainy season (Vollmann *et al*. 2010), it is heavily infested with grasses, sedges and broad leaved weeds. During the initial period, the crop growth is very slow which resulted vigorous growth of weeds in *kharif* season. Thus intense weed competition for nutrients, sunlight, space and water, reduces the crop productivity. If weeds are not controlled at critical stage that is 20-40 DAS period of crop-weed competition, there may be identical reduction in the seed yield of soybean. The yield losses due to uncontrol weeds are ranging from 31 – 84 % as reported by Karchoo *et al*. (2003). According to Kundu *et al.* (2011) the loss in yield of soybean due to weeds was 43% in control which indicates the necessity of controlling weed for exploiting the yield potential of soybean.

There are so many herbicides reported to control weeds in soybean but they are less effective to control. The pre-emergence herbicides like alachlor and metalachlor have been recommended for weed control in soybean and are being used by the farmers since long period. Presently, Imazethapyr is being in use as a post-emergence herbicide for controlling weeds in soybean (Patel *et al.* 2009). However, its efficacy has not been tested with Propaquizafop and Bentazone alone or in combination for wide spectrum weed control in soybean. At present, imazethapyr is being in use as a post-emergence herbicide for controlling weeds in soybean but some weeds had reported to uncontrol when imezethapyr was applied in alone (Patel *et al*. 2009).

Objective

Effect of post emergence herbicides on growth and yield of soybean'' has been proposed to conduct with an objective:

To see the effect of weed control treatments on growth and yield of soybean.

MATERIALS AND METHODS

A field experiment was conducted at Research farm, Department of Agronomy, Jawaharlal Nehru Kirshi Vishwa Vidyalaya, Jabalpur (M.P.) during *kharif* 2016. The soil of the experimental field was clay loam in texture, neutral in reaction (7.1), medium in organic carbon (0.60 %), available nitrogen (367 kg/ha), available phosphorus (16.23 kg/ha) and available potassium (317.10 kg/ha) contents. The ten treatments comprising of different doses of imazethapyr + propaquizafop (75+62.5 g/ha), imazethapyr + bentazone (75+75 and 75+62.5 g/ha), propaquizafop +bentazone (75+75 and 62.5+75 g/ha), and alone application of imazethapyr (100 g/ha), propaquizafop (75 g/ha) and bentazone (150 g/ha) as post-emergence, hand weeding twice at 20 and 40 DAS including weedy check, were laid out in randomized block design with 3 replications. Seeds were sown manually on 11th July 2016. The rows were opened with the help of pick axe and later sowing was done in each plot using a seed rate of 70

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kg/ha. Seeds were sown manually in each experimental plot keeping a row to row distance of 30 cm at the depth of 3-4 cm. The spray of herbicides was done with the help of knap-sack sprayer fitted with flat fan nozzle using 500 liters of water/ha. Other practices were adopted as per the recommendations.

The data on weeds were recorded by putting of 0.25 square meter (0.5 m x 0.5 m) was randomly placed at four places in each plot and then the species wise weed count was noted. At maturity, data on plant height, branches/plant, dry weight/plant, pods/plant, number of seeds/pod and 100-seeds were recorded. Grain yield and haulm yield were recorded on plot basis and harvest index was calculated. Data so collected were analyzed statistically using analysis of variance (ANOVA). Weed control efficiency (WCE) was calculated by the given formula: WCE= [(Dry weight of weeds in control plots- Dry weight of weeds in treated plots) *100]/ Dry weight of weeds in control plots. Gross returns were calculated by taking the sell price of soybean Rs 27.75/kg. Net returns and benefit:cost ratio were also worked out.

RESULTS AND DISCUSSION

There are several weed flora found in soybean but, *Trieanthema portulaca, Digera arvensis, Phyllanthus niruri, Commelina benghalensis, Convolvulus arvensis* are the most severe broad leaf weeds in soybean. Whereas, *Digitaria sangunalis, Echinocloa crusgalli ,Dactyloctenium aegyptium* and *Cyperus rotundus are the major narrow leaf weeds also found in soybean* under Kymore Plateau and Satpura hills zone of Madhya Pradesh (Kewat and Pandey 2001). The severe infestation of *Echinochloa crusgalli, Commelina communis, Cyperus rotundus, Phyllanthus niruri, Digitaria adscendens* and *Acalypha strumarium,* in soybean at Gwalior (MP). Dhane *et al.* (2009). Hence, due to the diverse weed flora, weed control become very difficult in *kharif* soybean.

All weed control treatments significantly reduced the weed dry weight (Table 1) at 45 DAA, the minimum dry weight of weeds was recorded in two hand weeding (20 and 40 DAS) which was significantly lower than all other weed control treatments. Among the different herbicide treatments, lowest weed dry weight, when recorded at 45 DAA during 2016, was recorded in Imazethapyr+Propaquizafop 75+62.5 g/ha at 20 DAS and which was at par with the application of Imazethapyr 100 g/ha, Imazethapyr + Bentazone 75+75 g/ha and Imazethapyr+Bentazone 75 + 62.5 g/ha. The maximum dry weight was recorded in weedy check plot similar results observed by Sandil *et al.* (2015).

Table 1. Effect of different weed control treatments on dry matter of weeds and weed control efficiency at 45 DAA in soybean.

Treatments	**Dose g/ha**	Total dry weight of weed	WCE %
T_1-Imazethapyr	100	117.81	70.76
T_2-Propaquizafop	75	155.61	61.38
T_3-Bentazone	150	232.28	42.35
T_4-Imazethapyr+Propaquizafop	75+62.5	109.96	72.71
T_5-Imazethapyr+Bentazone	75+75	127.40	68.38
T_6-Propaquizafop+Bentazone	62.5+75	146.16	63.72
T_7-Imazethapyr+Bentazone	75+62.5	135.70	66.32
T_8-Propaquizafop+Bentazone	75+75	139.87	65.28
T_9-Hand weeding(20 and 40DAS)	-	39.37	90.23
T_{10}-Weedy-check (Control)	-	402.91	0.00
SEm±		-	-
CD at 5%		-	-

Weed control efficiency (WCE) was calculated on the basis of weed biomass obtained under weedy check plots and other treatments. The data on WCE at 45 DAA are presented in Table1. Among the different weed control treatments, the higher WCE (72.71%) was found in plots receiving combined application of Imazethapyr+Propaquizafop 75+62.5 g/ha followed by alone application of Imazethapyr at

100 g/ha (70.76%). However WCE was further reduced with application of Bentazone in alone at 150 g/ha (42.35%) However, the WCE was maximum (90.23%) under hand weeding twice (20 and 40 DAS) in soybean (Thakre *et al.* 2015)

The weed management practices improved growth (plant height and branches/plant) and yield attributes (pods/plant and seeds/pod) of soybean over unweeded control (Table 2). The differences with the respect to plant height and branches/plant were found significantly, maximum plant height was recorded in two hand weeding which was significantly higher than all other weed management treatments and unweeded control. All the weed management treatments resulted in significantly higher branches/plant over unweeded control. This sows the application of Imazethapyr, Propaquizafop and Bentazone alone and combination had no adverse effect on growth of soybean. The application of Imazethapyr + Propaquizafop 75.0+62.5 g/ha registered highest number of pods/plant followed by combined application of Imazethapyr + Bentazone 75+75 g/ha and alone application of Imazethapyr 100 g/ha and significantly higher than all other weed control treatments. However hand weeding twice had the maximum pods/plant. Differences with respect to seeds/pod were found to be significant, the seeds per pod were numerically higher under weed free treatment closely followed by combined application of Imazethapyr + Propaquizafop at 75.0+62.5 g/ha and significantly higher than all other weed control treatments, while it was lowest under weedy check. The differences with respect to100-seeds were found to be non-significant. Similar work was also reported by Kulal *et al.* (2017).

The seed yield of weedy check plot was very poor (1104 kg/ha) due to maximum crop weed competition throughout the growing season. It increased markedly with the Bentazone 150 g/ha which gave the seed yield of 1323 kg/ha. This was at par with the alone application of Propaquizafop at 75 g/ha (1400 kg/ha). Alone application of Bentazone at 150 g/ha (1323 kg/ha) further increased the seed yield over Propaquizafop at 75 g/ha. But the difference between these treatments was not marked. It was noticed that alone application of Imazethapyr 100 g/ha markedly higher seed yield (1834 kg/ha) than alone application of Propaquizafop and Bentazone at 75 and 150 g/ha as well as the combined application of Propaquizafop+Bentazone 62.5+75 g/ha (1556 kg/ha) and Imazethapyr + Bentazone 75 +62.5 g/ha (1655 kg/ha). Among all the herbicidal treatments combined application Imazethapyr+Propaquizafop 75+62.5 g/ha registered maximum seed yield of 2100 kg/ha which was at par to hand weeding twice 2190 kg/ha. (Kulal *et al.* 2017). Haulm yield significantly varied due to different weed control treatments and the treatments exhibited almost similar trends as observed in case of seed yield. All the treated plots produced significantly higher haulm yield over weedy check. Haulm yield curbed higher at large extent with the application of Imazethapyr alone at 100 g/ha (3788 kg/ha) while the more pronounced increase in the yield was obtained with the combined application of Imazethapyr+Propaquizafop 75.0+62.5 g/ha (3900 kg/ha) which was at par to the obtained under hand weeding twice at 20 and 40 DAS. The ratio of economic yield and biological yield (HI) expressed in percentage was affected by various treatments Table 2. Among weed control treatments, the minimum harvest index was recorded in weedy check plots (23.69%). The combined application of Imazethapyr +Propaquizafop 75.0+62.5 g/ha had higher value of HI (35.00). Hand weeded plots had harvest index (34.41). Similar work was also reported by Kushwah and Vyas, 2005.

The combined application of Imazethapyr + Propaquizafop (75.0+62.5 g/ha) fetched the maximum net return of Rs 26585/ha followed by Imazethapyr + Bentazone 75+75 g/ha (Rs 21247/ha) and Imazethapyr 100 g/ha (Rs 19779/ha). B-C ratio was minimum (1.03) under weedy check. B-C ratio was maximum (1.75) with Imazethapyr + Propaquizafop (75.0 + 62.5g/ha) followed by Imazethapyr + Bentazone 75+75 g/ha (1.60) and application of Imazethapyr 100 g/ha alone (1.57) similar results observed by Bali *et al.*2016.

Table 2. Growth, yield attributes, yield and economics of soybean as influenced by different weed control treatments

Treatments	Dose g/ha	Plant Height	Branches /plant	Pods/ plant	Seeds/ pod	Seed index (g)	Seed yield (kg/ha)	Haulm yield (kg/ha)	Harvest index (%)	Net monetary returns (Rs/ha)	B:C Ratio
T_1-Imazethapyr	100	52.33	4.00	25.00	2.27	9.71	1834	3788	32.62	19779	1.57
T_2-Propaquizafop	75	48.08	3.40	23.62	2.00	9.62	1400	3927	26.28	8922	1.26
T_3-Bentazone	150	54.47	3.00	23.10	1.73	9.71	1323	2911	25.69	5659	1.17
T_4-Imazethapyr+Propaquizafop	75+62.5	53.73	4.47	26.10	2.40	9.93	2100	3900	35.00	26585	1.75
T_5-Imazethapyr+Bentazone	75+75	53.25	4.33	25.67	2.27	9.59	1903	3779	33.49	21247	1.60
T_6-Propaquizafop+Bentazone	62.5+75	48.85	3.40	24.00	2.07	9.82	1556	3892	28.56	11200	1.32

T_7-Imazethapyr+Bentazone	75+62.5	51.00	3.73	24.79	2.20	9.89	1655	3679	31.03	14390	1.41
T_8-Propaquizafop+Bentazone	75+75	49.97	3.60	24.38	2.13	9.60	1626	3812	29.90	12477	1.35
T_9-Hand weeding(20 and 40DAS)		55.30	4.73	26.87	2.47	10.07	2190	4176	34.41	19696	1.44
T_{10}-Weedy-check (Control)		47.30	2.40	22.12	1.53	9.22	1104	3556	23.69	939	1.03
SEm±		0.50	0.34	1.01	0.19	0.80	31.42	37.20	-		
CD at 5%		1.48	1.03	3.00	0.55	NS	94.56	110.60	-		

CONCLUSION

Application of Imazethapyer + Propaquizafop 75 + 62.5 g/ha had higher growth and yield of soybean followed by Imazethapyr+Bentazone 75+75 g/ha and proved superior than the other treatments.

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RESEARCH ARTICLE

EFFECT OF NITROGEN LEVELS AND WEED CONTROL METHODS ON GROWTH, YIELD AND ECONOMICS OF RICE (*ORYZA SATIVA* L.)

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Abstract: A field experiment was carried out during rainy seasons of 2015 at the Rajaula Agriculture Farm, MGCGVV, Satna (M.P.) to study the effect of N-levels and weed control methods on growth, yield and economics of rice. The application of 125 kg N/ha was found the best which produced maximum grain yield (22.58 q/ha) and net return (Rs.24889/ha) from transplanted rice var. PS-5. The weed control treatment W_6 (HW 20 & 40 DAS) proved the best which produced highest grain yield (25.44 q/ha) and net return (Rs.29470/ha) from rice. Among the treatment interactions, N_{125} with 2 HW performed the best by producing highest grain yield (27.78 q/ha) and net return (Rs.33018/ha) from transplanted rice var. PS-5. Butachlor 0.75 kg/ha + 2 HW stood the second best (rice grain yield 23.86 q/ha, income Rs.24963/ha). The best substitute of 2 HW with or without butachlor was butachlor + 2, 4-D 0.80 kg/ha or butachlor + bispyribac sodium (20 g/ha) which equally yielded 20.57 to 21.82 q/ha rice grain and gave net income from Rs.22531 to Rs.25334/ha.

Keywords: Nitrogen levels, Weed control methods, Growth, Yield, Economics, Rice

INTRODUCTION

Rice-wheat is one of the major cropping systems in the country. Both the crops are heavy feeder of nutrients which needs to be managed by improved technology including effective weed management.

Nitrogen is as a key nutrient in determining the level of crop productivity. The efficiency of applied nitrogen is very low and varies from 20 to 25% in upland rice crop due to the oxidized condition prevailing in uplands and concomitant heavy nitrogen loss through percolating water. Hence, fractional application of nitrogen in right amount and proportion and when it is needed the most seems to be a practical proposition. Weed control also facilitates higher absorption of applied nutrient, thus increases the efficiency of fertilizers application to the crops (Amarjit *et al.*, 2006).

Crop weed competition in direct sowing method is more severe reducing the yield by 20 to 95% (Gogoi, 1998). Manual weeding is expensive, laborious and time consuming as well as difficult in early stage of crop growth. Therefore, the use of pre-emergence herbicides has been found most effective in early stage only, but the second flush of weeds at 25-30 days after sowing (DAS) become problematic. Hence, an integrated weed management practice is the only effective alternative. The moderate nitrogen levels increase the crop yield independent of weed density but higher doses increase the risk of yield loss due to increased weed competition (Cavero *et al.*, 1997). In view of these facts, the present research was taken up.

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MATERIALS AND METHODS

The field experiment was carried out during rainy seasons of 2015 and 2016 at the Rajaula Agriculture Farm, MGCGVV, Satna (M.P.). The soil of the experimental site was sandy-loam in texture and neutral in soil reaction (pH 7.46). The soil was low in nitrogen, medium in phosphorus and high in potash. The total rainfall received during the crop season was 584.3 mm distributed in 31 rainy days.

The experiment was laid out in split plot design with treatments comprising three nitrogen levels viz. N_{75} (N_1), N_{00} (N_2) and N_{125} (N_3) as main-plot treatments and seven weed control treatments viz. (W_1-butachlor + 1 HW, W_2-butachlor + 2 MW, W_3-butachlor + 2,4-D, W_4-bispyribac sodium, W_5-butachlor + bispyribac sodium, W_6-HW-2, W_7-control) as sub-plot treatments. Before transplanting rice crop, an uniform dose of 60 kg P_2O_5 + 40 kg K_2O/ha was applied in all the plots through SSP and MOP, respectively. Nitrogen was applied through urea in 3 split doses i.e. 50% at basal, 25% at tillering and 25% at panicle-initiation stages. The rice crop (PS-5) was transplanted on 16 July in 2015 and on 19 July in 2016. The crop was harvested on 22 November in 2015 and on 12 November in 2016.

RESULTS AND DISCUSSION

Growth parameters

Application of different levels of nitrogen upto N_{125} significantly enhanced the plant height and tillers/m^2. Tallest plants (77.5 cm) and more tillers (307/m^2) were recorded under the highest N level (125 kg/ha).

This was the highest dose of nitrogen levels which might be due to the fact that nitrogen is essential for building up of protoplams and protein which induce cell division and initial meristematic activity. These findings are in close agreement with those of Mahajan *et al.* (2010), Pramanik and Bera (2012), Shwetha and Narayana (2014) and Kumar *et al.* (2015). Throughout the growth period all the weed control treatments (W_1 to W_6) recorded significantly higher plant height and tillers/m^2 as compared to W_7 (weedy check). At 30, 60 and 90 DAS stages of observations, all the weed control treatments recorded almost significant similar superiority over W_7 in respect to the plant height and tillers formation. Out of weed control treatments viz. W_3, W_5 and W_6 performed equally best in enhancing these growth characters.

The superiority in respect to growth characters recorded by all these weed control treatments over control at early and later stages of observations might be due to lesser weed competition than weedy check. Similar results were recorded by Maity *et al.* (2008), Noyingthung (2009), Akbar *et al.* (2011), Yadav *et al.* (2011) and Khalique *et al.* (2012).

Yield-attributes

Most of the yield-attributes like number of panicles/m^2, length and weight of panicle, filled grains count/panicle and test-weight showed the superiority under the highest N-level having 125 kg N/ha. Maximum panicles were 295/m^2, panicle length 20.2 cm and panicle weight 1.86 g, filled grains 92.50/panicle and 18.43 g test weight. In fact, nitrogen is one of the major plant nutrients and it is an integral part of the chlorophyll and all proteins, vigorous growth of plant height and tillers, leaf production and enlargement of leaf surface. This was simultaneously augmented the assimilation of nitrogen by reproductive parts of the plant thus resulting increased yield attributing parameters. Similar results have also been reported by Barik *et al.* (2008), Mahajan *et al.* (2010) Bai *et al.* (2013) and Vishwakarma *et al.* (2014).

The response of highest dose of nitrogen under study might be due to edaphology of site because soil was low in nitrogen content. So the nitrogen response was dominated. Similar findings have been reported by Rammohan *et al.* (2000), Meena *et al.* (2001), Satyanarayana *et al.* (2012) and Kumar *et al.* (2015).

It is evident from the results that hand weeding twice (W_6) exhibited significant superiority over all other weed control treatments in respect to yield-attributes like number of panicles/m^2, length of panicle, weight of panicle, number of filled grains and test weight. The maximum panicle number was 319/m^2, panicle length 22.0 cm, panicle weight 1.97 g, filled grains 96.89/panicle and test weight 19.59 g. This was followed by W_2. However, all other weed control treatments were also significantly superior over W_7 (unweeded control). The higher values of yield-attributes recorded by W_6 and W_2 over all other weed control treatments might be due to better control of monocot and dicot weeds which facilitated to greater availability of plant nutrients and ultimately improved yield-attributes. These results are in the close agreement with the findings of Maity *et al.* (2008), Mishra and Singh (2008), Noyingthung (2009), Mehta *et al.* (2010), Yadav *et al.* (2011), Akbar *et al.* (2011) and Khalique *et al.* (2012).

Productivity parameters

Among the applied nitrogen levels, the highest N level (N_{125}) performed the best by producing significantly highest grain yield i.e.22.58 q/ha as compared to lower N-levels. This might be due to over all better performance of growth and appreciable improvement in yield-attributing characters viz. number of panicles/m^2, number of filled grains/panicle, length and weight of panicle and test weight. Mahajan *et al.* (2010), Pramanik and Bera (2012 and 2013), Bai *et al.* (2013), Shwetha and Narayana (2014), Vishwakarma *et al.* (2014), Show *et al.* (2014) and Kumar *et al.* (2015) have also found an increase in grain yield of rice with the application of nitrogen up to 150 kg/ha.

The straw yield was found highest under the treatment having lowest 75 kg N/ha. The lowest N level produced 40.76 q/ha straw yield which was significantly superior to the higher N levels. The decrease in straw yield under highest N supply might be due to the better performance of the nitrogen on production of grain over is straw.

The significantly highest grain yield (25.45 q/ha) was recorded by W_6 (HW twice), while second best treatment was W_2 (23.86 q/ha), followed by W_3 and W_5 (21.82 and 20.57 q/ha, respectively). The lowest grain yield was recorded by W_7 which produced only 12.89 q/ha grains. Like grain yield, straw yield was also recorded highest by W_6 (45.40 q/ha), followed by W_2 (41.54 q/ha) which was significantly higher than the remaining treatments, while the lowest straw yield was recorded by W_7 (27.78 q/ha). The straw yield was exactly in accordance with the growth parameters in these treatments. The similar yield results were also found by Noyingthung (2009), Mehta *et al.* (2010), Mandal *et al.* (2011), Yadav *et al.* (2011), Akbar *et al.* (2011) and Khalique *et al.* (2012).

Economical gain from rice

Application of nitrogen up to 125 kg/ha proved the most remunerative giving net return up to Rs.24889/ha, whereas the lowest nitrogen level (75 kg/ha), resulted in the lowest net return (Rs.16893/ha). This was higher by Rs.7996/ha. The higher net return due to increased nitrogen dose may be due to increased growth, yield and yield-attributing parameters which fetched increased market value (gross income). Thus, the higher grain and straw yield means higher net income. The B:C ratio eventually followed the same trend because it is the another way of expressing profitability among the various treatments.

Table 1. Growth parameters and yield-attributes of rice (PS-5) as influenced by different treatments (Pooled for 2 years)

Treatments	Plant height (cm) at 90 DAS	Number of tiller/m^2 (90 DAS)	Weed population/ m^2 at 55 DAS	Weed dry weight (g/m^2) at 55 DAS	Numbers of panicles/m^2	Length of panicle (cm)	Weight of panicle (g)
Nitrogen levels(kg/ha)							
N_{75}	71.5	283.1	45.3	41.3	260.3	17.9	1.49
N_{100}	75.3	285.0	49.6	48.6	271.9	19.2	1.70
N_{125}	77.5	307.2	57.0	57.5	295.0	20.2	1.86
CD (5%)	**2.93**	**9.74**	**1.63**	**0.70**	**14.66**	**0.62**	**0.14**
Weed control methods							
W_1-Buta. (0.75 kg/ha) + 1 HW	72.3	294.1	47.6	34.4	274.1	18.4	1.73
W_2-Buta. + 2 MW	78.2	319.1	40.3	35.5	304.1	21.0	1.90
W_3-Buta. + 2, 4-D (0.80 kg/ha)	76.6	308.3	39.0	27.8	292.8	19.7	1.83
W_4-Bispyribac(20 g/ha)	72.1	280.1	58.5	51.4	266.3	18.0	1.69
W_5-Butachlor + Bispyribac	74.7	299.7	34.0	29.9	283.7	18.6	1.77
W_6-Hand weedings (2)	78.5	328.8	22.7	24.1	319.0	22.0	1.97
W_7- control	69.1	212.4	112.3	141.2	190.2	16.0	0.94
CD (5%)	**2.58**	**10.88**	**1.92**	**0.76**	**13.58**	**0.76**	**0.135**
Interactions	**Sig.**	**Sig.**	**Sig.**	**Sig.**	**NS**	**NS**	**NS**

Table 2. Yield-attributes, yield and economics of rice (PS-5) as influenced by different treatments (Pooled for 2 years)

Treatments	Number of filled grains/ panicle	Number of unfilled grains/ panicle	Test weight of 1000-grains(g)	Grain yield (q/ha)	Straw yield (q/ha)	Harvest index (%)	Weed control efficiency (%) 55 DAS	Net income (Rs/ha)	B:C ratio
Nitrogen levels(kg/ha)									
N_{75}	89.89	10.13	16.25	18.02	40.76	30.52	54.37	16893	1.72
N_{100}	90.85	9.27	17.29	20.16	36.67	35.30	55.45	20450	1.86
N_{125}	92.50	7.50	18.43	22.58	35.44	38.64	54.49	24889	2.04
CD (5%)	**1.63**	**0.65**	**0.98**	**0.97**	**1.30**	**1.30**	**NS**	**--**	**--**
Weed control methods									
W_1-Buta. (0.75 kg/ha) + 1 HW	95.30	4.72	16.83	19.22	37.14	33.73	57.74	17790	1.73
W_2-Buta. + 2 MW	94.02	6.00	19.38	23.86	41.54	36.57	63.88	24963	1.93
W_3-Buta. + 2, 4-D (0.80 kg/ha)	92.42	7.60	17.72	21.82	38.59	36.19	65.43	25334	2.15
W_4-Bispyribac(20 g/ha)	89.99	10.03	15.72	17.98	35.28	33.71	47.80	17521	1.80
W_5-Butachlor + Bispyribac	92.32	7.71	17.36	20.57	37.62	35.33	69.61	22531	2.01
W_6-Hand weedings (2)	96.89	3.14	19.59	25.45	45.40	36.25	78.92	29470	2.14
W_7- control	76.63	23.39	14.66	12.89	27.78	31.63	0.00	7600	1.37
CD (5%)	**1.81**	**0.78**	**1.09**	**1.09**	**1.45**	**1.45**	**2.45**	**--**	**--**
Interactions	**NS**	**Sig.**	**NS**	**NS**	**Sig.**	**Sig.**	**NS**	**--**	**--**

Amongst the weed control treatments, W_6 (having hand weeding twice) gave the maximum net return up to Rs.29470/ha, followed by W_3 (butachlor + 2,4-D) or W_2 (butachlor + 2 MW) Rs.25334 or Rs.24963/ha respectively. The lower net return (Rs.17521 to Rs.17790/ha was noted from W_1 (buta.+1 HW) and W_4 where bispyribac sodium only was applied. Both these treatments gave lower yield thereby lower monetary gain. The control (W_7) gave a monetary gain only up to Rs.7600/ha which may be due to decreased growth and yield of crop as a result of increased weed competition for light, space, moisture and nutrients with the crop plants. The lowest crop yield under W_7 treatment means lowest market sale of the produce (lowest gross income).

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RESEARCH ARTICLE

TECHNOLOGY TRANSFER THROUGH FIELD TRIALS FOR INCREASING PRODUCTIVITY AND PROFITABILITY OF PIGEON PEA

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Abstract: Pigeon pea is one of the major *kharif* crop grown in district. Farm Science Centre known as KrishiVigyan Kendra laid down Front Line Demonstration in the year 2017-18 to 2018-19introducing new and high yielding variety "Rajiv Lochan" applying scientific practices in their cultivation. The FLDs were carried out in different villages of Surguja district. The productivity and economic returns of pigeon pea in improved technologies were calculated and compared with the corresponding farmer's practices (local check). Improved practices recorded higher yield as compared to farmer's practices. The improved technology recorded higher yield of 17.47 over farmers practice 9.89 q/ha. In spite of increase in yield of pigeon pea, technology gap, extension gap and technology index existed. The variation in per cent increase in the yield was found due to the lack of knowledge, and poor socio economic condition. It is concluded that the FLDs programmes were effective in changing attitude, skill and knowledge of improved package and practices of HYV of pigeon pea adoption.

Keywords: Pigeon Pea, FLDs, Economic impact, Adoption

INTRODUCTION

Pulses are of greatest importance in human diet. India is the major pulse producer, importer and consumer country of the world. In 2013, the total area and production of pulses in world was 81.0 million hectares and 73.21 million tonnes respectively. Pigeon pea (*Cajanuscajan* L. Millsp.) is a crop of vital importance in tropical countries, especially in India, where it is used as major source of protein in human diets. It is also cultivated in Australia, USA, Africa, Indonesia and some countries in South America because of its nutritional qualities and drought tolerance (Faris 1983). The total area under pigeon pea cultivation in India is 3.4 million hectare with a total production of 2.8 million tons (2003–2004). The potential yield of pigeon pea is 1.5–1.7 tons per hectare. While, only 0.58 tons per hectare is harvested at farmers field (Joshi et al. 2006). Numerous production constraints are responsible for this wide gap between potential and realized yield. Pigeon pea phenology is strongly affected by temperature (Hodges 1991; Jones et al. 1991; Ritchie and NeSmith 1991) and photoperiod (Omanga et al. 1996) emphasized that the effect of temperature on the rates of pigeon pea development can be similar in magnitude to those of photoperiod. The optimum range of temperature for proper growth and development of pigeon pea is 18–38°C (Van der Maesen 1989). Whereas in the controlled environment showed that warm (>28°C) and cool (<20°C) temperature delay flower initiation and that the optimal temperature for flowering for early maturing type is close to 24°C (Turnbull et al. 1981).

India contributed 34.77 % (28. 17 million hectares) and ranks first in the harvested area of total pulses followed by Niger (6 %) and Nigeria (4.80 %) in the world and ranks first in pulses production accounting about 25.01 percent (18.31 million tonnes) of the total production worldwide (Indiastat 2013). The world's total yield was about 9038 hectogram per hectare and India was at 176th position with 6500 hectogram per hectare (FAOSTAT 2015). Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Karnataka, Andhra Pradesh, Chhattisgarh, Tamil Nadu, Odisha and Jharkhand are the ten major pulses growing states and account for 90 percent of total pulse production and area. The total consumption of pulses in India was 21.74 million tonnes of which 4.58 million tonnes were imported and total production was 17.19 million tonnes during 2014-15 (Indiastat 2015).

Pigeon pea is second most important pulse crop of India after chickpea which is well balanced nutritionally. It is a multipurpose crop providing food, fodder, feed, fuel, functional utility, forest use and fertilizer in context of sustainable agriculture (Gowda et.al. 2015). It is an excellent source of protein (21.7g /100g), dietary fibres (15.5g /100g), soluble vitamins, minerals and essential amino acids (18, 5). Pigeon pea is also used in traditional medicines and leaves, flowers, roots, seeds are used for the cure of bronchitis, sores, respiratory ailments and also acts as an alexeritic, anthelmintic, expectorant, sedative, and vulnerary (Saxena et.al. 2010). India is one of the major pigeon pea producing countries with 63.74 percent of total global production followed by Myanmar (18.98 percent), Malawi (6.07 percent), Tanzania (4.42 percent) and Uganda (1.98 percent) (Gowda et.al. 2015). The total area under pigeon pea cultivation during 2014-15 was ~3.9 million hectares producing

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around 2.81 million tonnes of pigeon pea with an average national productivity of 729 kg/ha (Indiastat 2015). Pigeon pea is often cross pollinated crop. It is very difficult to maintain genetic purity of seed at farm level. Therefore, well organised seed production plan in each agro-climatic zone by involving farmers and other stakeholders is necessary for multiplication and supply of seeds of improved and high yielding varieties to farmers. It was observed that in recent past a number of improved varieties of pulses have been released for cultivation. But in 2010-11, the seed replacement rates (SRR) of pulses and pigeon pea were only 22.51 percent and 21.23 percent respectively Singh 2011). The farmers still use traditional/their own saved and developed varieties of seeds. High yields, resistance to pest attack, synchronous maturity time and other characteristics such as cooking quality, taste and storability are key criteria used by farmers in making a choice of any crop including pigeon pea (Manyasa et.al. 2009). Pigeon pea is mainly cultivated in Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Uttar Pradesh, Gujarat, Jharkhand, Odisha and Tamil Nadu. About 98 percent of total cultivation area of pigeon pea is occupied by these ten states in India (Indiastat 2015).

MATERIALS AND METHODS

Front line demonstration (FLDs) on pigeon pea varieties were conducted by KrishiVigya Kendra, Surguja, Chhattisgarh during the period from 2017-18 to 2018-19 in different villages of district Surguja. The total 4 number of demonstration were conducted in these villages. The gap in farmer's practices and recommended practices was observed as per adoption level of scientific recommended package and practices for cultivation of crop by farmers. The component demonstration of front line technology in pigeon pea was comprised i.e. improved variety Rajeev lochan proper tillage, proper seed rate and sowing method, balance dose of fertilizer (20:60:30 kg/ha NPK), use of PSB @ of 5g/kg of seed as seed treatment, weed management and protection measure (Table-1). Total 1.5 ha of area was covered in two consecutive years. In the demonstration, one control plot was also kept where farmers practices was carried out. The FLDs were conducted to study the technology gap between the potential yield and demonstrated yield, extension gap between demonstrated yield and yield under existing practice and technology index. The yield data were collected from both the demonstration and farmers practice by random crop cutting method and analysed by using simple statistical tools. The technology gap, extension gap and technological index (Samui et al. 2000) were calculated by using following formula as given below-

$$\textbf{Percent increase yield} = \frac{\text{Demonstration yield-farmers yield}}{\text{Farmers yield}} \times 100$$

$$\textbf{Technology Index} = \frac{\text{Potential yield- Demonstrated yield}}{\text{Potential yield}} \times 100$$

Technology gap= Potential yield-Demonstrated yield
Extension gap= Demonstrated yield – Yield under existing practice

RESULTS AND DISCUSSION

In Chhattisgarh Asha, UPAS-120 and Pragativarieties of Pigeon pea adopted in Surguja district. The gap between the existing and recommended technologies of pigeon pea in district Surgujawere presented in Table-1 & 3. Full gap was observed in most of the farmer's practices except time of sowing and seed rate where partial gap was observed, which definitely resulted the reduction in potential yield. Farmers were not aware about recommended technologies. Farmers in general used degenerated seeds of local varieties instead of the recommended high yielding resistant varieties (wilt and sterility mosaic). Unavailability of seed in time and lack of awareness were the main reasons. Farmers followed broadcast method of sowing against the recommended line sowing with proper spacing and because of this, they applied higher seed rate than the recommended.

Table 1. Difference between Technological intervention and farmers' practices under FLD in Pigeon Pea.

S. No.	Particulars	Technological intervention	Existing practices	Gap
1	Farming situation	Rainfed	Rainfed	Full gap
2	Variety	Rajiv Lochan	Local variety	Full gap
3	Time of sowing	1st week of July	1st week of August	Partial Gap

4	Method of sowing	Line Sowing	Broadcast	Full gap
5	Seed treatment	Carbendazim&Trichoderma @ 5g /kg seed	No seed treatment	Full gap
6	Seed rate	20 kg/ha	30 kg/ha	Partial Gap
7	Fertilizer dose	N:P:K=20:60:30 kg/ha	Imbalance	Full gap
8	Plant Protection	Trizophos + Cypermethrin @ 2.0 ml/l water	No plant protection	Full gap
	Weed management	Imaazathaper@150 g/ha	No weed management	Full gap

Yield attributes

During two years of frontier technologies result obtained in Table 2. The results revealed that the FLDs on pigeon pea an average yield was recorded 17.47 q/ha under demonstrated plots as compare to farmers practice 9.89 q/ha. The highest yield in the mother trials plot was 18.30 q/ha and in farmers practice 10.25 q/ha during 2018-19. This results clearly indicated that the higher average grain yield in demonstration plots over the years compare to local check due to knowledge and adoption of full package of practices i.e. appropriate varieties such as Rajeev Lochan, timely sowing, proper spacing, seed treatment with *PSB* @ 5g/kg of seed, use of balanced dose of fertilizer, method and time of sowing, timely weed management and need based plant protection. The average yield of pigeon pea increased 76.53%. The yield of pigeon pea could be increased over the yield obtained under farmers practices (use of non-descriptive local variety, no use of the balanced dose of fertilizer, untimely sowing and no control measure adopted for pest management) of pigeon pea cultivation (Singh *et al.* 2002).

Table 2. Yield, technology gap, extension gap and technological index of pigeon pea variety Rajeev Lochan under FLDs.

Year	Trial	Area (ha.)	Average Yield (q/ha.)		% Increase	Technology Gap (q/ha.)	Extension Gap (q/ha.)	Technological Index(%)
			Trial	Farmers Practices				
2017-2018	**FLDs**	1.50	16.65	9.54	74.53	3.35	9.54	16.75
2018-2019	**Mother trial**	1.20	18.30	10.25	78.54	1.7	8.05	8.50
Total/Average		**2.70**	**17.47**	**9.89**	**76.53**	**2.52**	**8.79**	**12.62**

Technology gap

The technology gap, the differences between potential yield and yield of demonstration plots were 3.35 and 1.7 q/ha during 2017-18 and 2018-19 respectively. On an average technology gap under two year FLDs and mother trial programme was 2.52 q/ha. The technology gap observed may be attributed to dissimilarity in the soil fertility status, agricultural practices and local climatic situation.

Extension gap

Extension gap of 9.54 and 8.05 q/ha was observed during 2017-18 and 2018-19 respectively. On an average extension gap was observed 8.79 q/ha which emphasized the need to educate the farmers through various extension means i.e. front line demonstration for adoption of improved production and protection technologies, to revert the trend of wide extension gap. More and more use of latest production technologies with high yielding varieties will subsequently change this alarming trend of galloping extension gap.

Technology index

The technology index shows the feasibility of the demonstrated technology at thefarmer's field. The technology index varied from 8.50 to 16.75% (Table-2). On an average technology index was observed 12.62%, which shows the efficacy of good performance of technical interventions. This will accelerate the adoption of demonstrated technical intervention to increase the yield performance of pigeon pea.

CONCLUSION

The FLDs produces a significant positive result and provided the researcher an opportunity to demonstrate the productivity potential and profitability of the latest technology (Intervention) under real farming situation, which they have been advocating for long time. The productivity gain under FLDs over existing practices of pigeon pea cultivation created greater awareness and motivated the other farmers to adopt suitable production technology of pigeon pea in the district. Therefore, for enhancing the production & productivity of pigeon pea crop, strategy should be made for getting the more and more recommended technologies adopted by the farmers.

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RESEARCH ARTICLE

EFFECT OF AGRONOMIC MANAGEMENT PRACTICES ON GROWTH, YIELD AND ECONOMICS OF GREENGRAM (*VIGNA RADIATA* (L.) WILCZEK)

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Abstract: A field experiment was carried out during summer season 2014 at the Research Farm, JNKVV College of Agriculture, Tikamgarh (M.P.) to study the effect of agronomic management practices on growth, yield and economics of greengram. Amongst the agronomic management practices, application of $N_{20}P_{50}K_{20}$ alongwith one or two hand weedings and spraying of insecticides (two spray each of quinlosphos 2 ml/litre and dimethoate 2 ml/litre) i.e. T_{11} and T_{12} brought about equally maximum growth and yield attributes thereby highest yield of greengram var. SML 668 (693 to 712 kg/ha) and net income (Rs.30479 to Rs.30539/ha). The findings indicate that the combined input of fertilizer (RDF), hand weeding and insecticidal spray is essential to obtain maximum benefit from greengram sown in the summer season.

Keywords: Agronomic management practices, Greengram

INTRODUCTION

Agronomic management plays an important role for realizing higher productivity of improved crop variety. In summer green gram, a high reduction in yield has been reported to occur due to non-use of fertilizers (Singh and Sekhon. 2008), lack of weeding (Singh *et al.,* 2014) and non-adoption of plant protection measures (Borah and Guha 1994). Adoption of improved agronomic practices significantly improved the yield attributes and yield of green gram (Siag and Mann 2004). It is, therefore, essential to use all these inputs/practices for realizing high grain yields. The relative contribution of different inputs in influencing the grain yield, however, varies in different crops. Singh and Sekhon (2002) reported that weed control was the single most important input followed by fertilizers, plant protection and *Rhizobium* inoculation in influencing the grain yield of summer greengram. However, due to high cost of inputs, the farmers might not use all these inputs. Moreover, farmers do not know the relative importance of different inputs for obtaining high grain yields. Keeping in view of above facts, the field experiment was taken up.

MATERIALS AND METHODS

The field experiment was conducted during the summer season 2014 at the Research Farm, JNKVV College of Agriculture, Tikamgarh (M.P.). The experimental soil was silty clay-loam in texture. The soil of the experimental field was clayey loam having pH 6.7, electrical conductivity 20 dS/m, organic carbon 0.5%, available N, P_2O_5 and K_2O 264, 25.7 and 254 kg/ha, respectively. The rainfall during summer season was 10.9 mm. The treatments comprised 12 agronomic management practices (Table 1) which were laid out in randomized block design keeping three replications. The greengram var. SML 668 was sown on 29 March,2014 @ 30 kg seed/ha keeping 30 cm x 10 cm planting geometry. The fertilizers $N_{20}P_{50}K_{20}$ were applied as basal according to the treatments. In all four irrigations were given. The crop was harvested on 14 June, 2014.

RESULTS AND DISCUSSION

Plant growth

Growth parameters like plant height, number of primary branches/plant and leaf area index differed significantly due to different agronomic management practices. The combination of two hand weedings (20 and 40 DAS) + fertilizer application + plant protection measures (T_{12}), which was found statistically at par with combination of one hand weeding (20 DAS) + fertilizer application + plant protection measures (T_{11}) and combination of two hand weeding (20 and 40 DAS) + fertilizer application (T_7) recorded significantly the highest plant height and more number of branches/plant at different growth intervals and at harvest. The significantly better growth of green gram with these treatments clearly indicated that all the 3 practices *viz*., weed control, fertilizer application and plant protection measures had positive effect on growth parameters as compared to other agronomic management practices, whereas the lowest plant height, number of branches/plant and leaf area index recorded where none of the weed control, fertilizer application and plant protection measure were adopted. These results are in line with the findings of Singh and Sekhon (2002), Singh and Sekhon (2008) and Asaduzzaman *et al*. (2010).

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Similarly, total dry biomass and its partitioning into leaf, stem and pods (g/plant) were also produced under agronomic management practice *i.e.*, combination of two hand weeding control (20 and 40 DAS) + fertilizer application + plant protection measures (T_{12}) and found statistically at par with agronomic management practices of combination of one hand weeding (20 DAS) + fertilizer application + plant protection measures (T_{11}) and combination of two hand weeding (20 and 40 DAS) + fertilizer application (T_7). The better growth of plants in terms of plant height, number of branches and leaf area index resulted into higher dry biomass accumulation of plants in these treatments.

The control plot (T_1) in which no agronomic management practices were applied, recorded significantly poor growth in term of plant height, number of branches/plant and leaf area index reflected into lesser total dry biomass accumulation and its partitioning into different plant parts at all growth intervals and at harvest. When there was no fertilizer application, no weed control and no plant protection, plants became thin and leaf enlargement and thickness of branching were adversely affected due to more and fast consumption of inputs (nutrients and moisture) by weeds and more infestation of insect-pest and diseases, where none of weeding, fertilizer application and plant protection measures were adopted. Similar results were reported by Khan and Khan (2005), Singh and Sekhon (2008) and Asaduzzaman *et al*. (2010).

Yield-attributes and yield

The seed yield of green gram differed significantly due to different agronomic management practices. The significantly highest seed yield (712.2 kg/ha) was recorded under the agronomic management practice combination of two hand weeding (20 and 40 DAS) + fertilizer application + plant protection measures (T_{12}) and found statistically at par with combination of one hand weeding (20 DAS) + fertilizer application + plant protection measures (T_{11}) and combination of two hand weeding (20 and 40 DAS) + fertilizer application (T_7). The favourable effect of combined use of weeding, fertilizer and plant protection measures on sink component (number of effective pods, number of seeds/pod and test weight) could be attributed to the higher seed yield recorded under T_{12}, T_{11}, and T_7 treatments. These results corroborate the findings of Singh and Sekhon (2002), Khan and Khan (2005), Singh and Sekhon (2008) and Asaduzzaman *et al*. (2010).

Agronomic management treatments *viz*., T_{12} (combination of two hand weeding (20 and 40 DAS) + fertilizer application + plant protection measures), T_{11} (combination of one hand weeding (20 DAS) + fertilizer application + plant protection measures), and T_7 (combination of two weeding (20 and 40 DAS) + fertilizer application) increased the seed yield by 130.4%, 124.2%, and 117.0%, respectively over control, 37.2%, 33.5%, and 29.2%, respectively over application of RDF alone (T_4), 60.6%, 56.3% and 51.3%, respectively over application of plant protection alone (T_5), 37.3%, 33.6% and 29.3%, respectively over application of RDF + PP (T_{10}), 32.2%, 28.7% and 24.5%, respectively over application of one weeding at 20 DAS (T_2) and 14.6%, 11.5% and 7.97%, respectively over application of two hand weedings at 20 DAS and 40 DAS (T_2). In other words, weed control was the most limiting factor, followed by fertilizer application and plant protection measures. Similar results were reported by Singh and Sekhon (2002). Effective weed control had been reported to increase the seed yield of summer green gram considerably (Varshney and Chary, 2000). The results suggest that to obtain the higher seed yield, all the 3 practices *viz*., weed control, fertilizer and plant protection measures should be followed. In case farmers, due to one or the other reason, want to skip any practice, they may skip plant protection but not the weed control. Sekhon *et al*., 1993, Borah and Guha, 1994 and Singh and Sekhon, 2002 also reported weed control to be the most important input in summer green gram.

The control treatment (T_1) recorded significantly lowest seed yield of 309.6 kg/ha. The reduction in the seed yield in control treatment could be attributed to poor yield attributes *viz*., number of effective pods/plant, number of seeds/pod and test weight of 1000-seeds on account of decreased growth in term of plant height, number of branches, leaf area index and lesser dry biomass accumulation. These results are in line with the findings of Singh and Sekhon (2008) and Asaduzzaman *et al*. (2010).

Table 1. Growth, yield-attributes, yield and economics of greengram as influenced by different agronomic management

Treatments	Plant height (cm)	Primary branches/ plant	Leaf area index	Number of effective pods/ plant	Number of seeds/ pod	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Net monetary return (Rs/ha)	B:C ratio
T_1: Control (no weeding, no plant protection and no fertilizer)	36.9	3.1	0.65	9.30	9.0	41.6	309.1	1284.0	19.4	10827	0.85
T_2: One hand weeding at 20 DAS (W_1)	41.6	3.6	0.71	11.9	9.8	42.3	538.7	1734.3	23.7	24082	1.47
T_3: Two hand weeding at 20 DAS and 40 DAS (W_2)	42.8	3.6	0.72	12.4	9.8	42.1	621.4	1925.3	24.4	28790	1.61
T_4:RDF ($N_{20}P_{50}K_{20}$)as basal	39.7	3.4	0.67	10.5	9.5	42.9	519.1	1884.0	21.6	22765	1.38

dose (F)											
T_5: Plant protection (PP)	38.6	3.2	0.66	10.0	9.4	41.6	443.4	1658.0	21.1	19629	1.41
T_6: One hand weeding at 20 DAS (W_1) + F	47.8	4.0	0.76	13.7	10.2	42.1	659.2	1876.2	26.0	29246	1.46
T_7: Two hand weeding at 20 DAS and 40 DAS (W_2) + F	50.9	4.7	0.78	15.3	10.4	41.8	670.9	1870.4	26.4	28644	1.33
T_8: One hand weeding at 20 DAS (W_1) + PP	43.7	3.7	0.73	12.6	9.9	41.8	622.8	1898.6	24.7	29183	1.66
T_9: Two handweeding at 20 DAS and 40 DAS (W_2) + PP	44.8	3.8	0.74	13.6	10.0	42.3	648.2	1883.7	25.6	29556	1.56
T_{10}: RDF as basal dose (F) + PP	40.2	3.4	0.69	11.4	9.6	41.8	518.8	1797.1	22.4	21535	1.22
T_{11}: One hand weeding at 20 DAS (W_1) + F + PP	51.5	4.9	0.78	15.5	10.4	43.0	693.1	1845.8	27.3	30539	1.44
T_{12}: Two hand weeding at 20 DAS and 40 DAS (W_2) + F + PP	52.4	5.0	0.80	16.1	10.5	43.2	712.2	1849.8	27.8	30479	1.35
CD (P=0.05)	**2.48**	**0.26**	**0.03**	**0.99**	**0.33**	**1.70**	**47.3**	**159.5**	**2.11**	**--**	**--**

Economics

The data clearly revealed that the combination of two hand weeding (20 and 40 DAS) + fertilizer application + plant protection (T_{12}) and weed control (20 DAS) + fertilizer application + plant protection (T_{11}) resulted into the net monetary return (Rs. 30539 and Rs. 30479/ha, respectively) as compared to other treatments. The higher NMR with these treatments was due to higher seed and straw yields in these treatments. However, minimum NMR (Rs.10827/ha) was recorded in control plots because of lower seed and straw yields. These results corroborate the findings of Singh and Sekhon (2002) and Singh and Sekhon (2008).

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RESEARCH ARTICLE

EFFECT OF DATES OF SOWING ON GROWTH, YIELD AND ECONOMICS OF SMALL MILLETS

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Abstract: A field experiment was carried out during rainy season 2017 at the Instructional Farm, JNKVV College of Agriculture, Rewa (M.P.).To study the effect of dates of sowing on growth, yield and economics of small millets. The growth and development of kodo millet was found superior followed by little millet and then barnyard millet under the influence of normal sowing date. The 15 July (normal sowing) was found the best sowing date for mitigating the climatic changes on kodo millet, little millet and barnyard millet, followed by early sowing and late sowing dates. The maximum grain yield (17.75 q/ha) and net income (Rs 33962/ha) was obtained when kodo millet was sown on 15th July.

Keywords: Dates of sowing, Growth, Yield, Economics, Small millets

INTRODUCTION

Small millets *(viz.* Kodo, Kutki, Ragi, Sawa, Cheena*)* are the small grained cereal crops belonging to the family *poaceae* (*Gramineae*). Small millets are mainly grown for food and feed purposes in the dry regions of world with limited alternatives for earning cash income and no crop insurance under harsh environments. Madhya Pradesh contributes about 50% area and 35% production of total millet in the country. The state of Madhya Pradesh ranks first among Kodo and kutki growing states in the country. Small millet occupies an area of 3.32 lakh hectare with the production of 0.92 lakhs tonnes in the state of Madhya Pradesh. Study conducted at Dharwad reveals that early sowing recorded significantly higher dry matter production (103.73 g) at maturity which decreased with delayed sowing (86.2 g). The number of effective tillers was higher in early planting crops with early maturity. The grain yield was maximum (7.38 q/ha) in proso millet sown in first fortnight of June (Palled *et al.* 2001). Thus the different small millets react differently in their productivity under normal, early or late sowing dates as reported by Patel and Patel (2002), Kamara *et al.* (2009) and Bashir *et al.* (2015). Looking to these facts, the present research was taken up under the existing agro-climatic conditions of Kymore plateau of M.P.

MATERIALS AND METHODS

The field experiment was carried out during the rainy season 2017 at the Instructional Farm, JNKVV College of Agriculture, Rewa (M.P.). The experimental soil was silty clay-loam in texture. The soil reaction was normal (PH 7.17). The available nitrogen in soil was low (238 kg/ha) while experimental filed was medium in available phosphorus (18.8 Kg/ha) and high in available potash (357 kg/ha). The electrical conductivity was 0.31 d s/m and organic carbon 0.67%. The experiment was laid out in a factorial randomized block design with three replications. The treatments comprised three small millets (kodo millet, little millet, and barnyard millet) and three date of sowing, (1st July, 15th July and 30th July). Thus the 9 treatment combinations were formed in one replication. The experiment were sown on 01, 15 and 30 July, 2017 keeping a seed rate of 10, 7 and 8 kg/ha and row spacing 22.5 cm and plant spacing 7 cm. the fertilizers were applied as per treatment. The crop was grown totally under rainfed condition. The total rainfall during the crop season was 256.89 mm with rainy days. The crop was harvested on 18 October, 2017.

RESULTS AND DISCUSSION

Growth parameters

The growth parameters of small millets revealed that the plant height, number of tillers/m^2, number of leaves/plant and leaves/plant were found to differ significantly amongst the small millets. The small millet differences amongst these growth characters were highly different. For example barnyard millet was found highest in plant height (109.14 cm), kodo millet was highest in tillers number (240.75/m^2), it was highest in number of leaves 18.76/plant. On the other hand, kodo millet was found lowest in plant height (80.76 cm), barnyard millet lowest in tillers count (184.00/m$_2$), kodo millet was lowest in leaves count (16.09 /plant). So much variation in growth parameters in different varieties was owing to variations in their genetic inheritance in these characters. In fact the growth parameters among the small millets are genetically governed. Such type of

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observations among the small millet have also been reported by Craufurd and Bidinger (1989)

As regards with the dates of sowing, 15th July sowing recorded maximum plant height (101.34 cm), tillers (225.33/m^2), leaves (17.52/plant). On the other hand, the corresponding values of late sowing (30th July) were almost significantly lowest (89.92 cm height, 203.43tillers, 16.07 leaves,). The maximum growth parameter under timely sowing may be owing to the immediate availability of favorable condition in the requisite of small millets. The increase height tillering and leaves number might be due to role of favorable temperature in rapid multiplication of tissues and increase in amount of growth substances such as normally occurring phytohormones and increase in auxin supply with higher level_Patel and Patel (2002), Kamara *et al.* (2009) Bashir *et al.* (2015).

Yield attributing characters

The yield attributing characters viz. number of panicles/plant, number of grains/panicle, length of panicle, weight of grains/panicle and 1000 grain weight were found to deviate up to significant extent due to different small millet and date of sowing. Out of three small millet, kodo millet brought about significantly higher number of panicles 248.15/plant over all the remaining millets. However, the other yield attributing characters were in the highest range case of little millet (234.22 grains/panicle, and barnyard millet was 24.37 cm panicle length, 0.71 g grains weight/panicle and 3.61 g 1000 grain weight in case of kodo millet). In case of kodo millet the grains/panicle, panicle length and grains weight/panicle were in the lowest range whereas 1000 grains weight was in the barnyard millet (2.02g). These type variations may be owing to variations in the genetic build up of the small millets. In fact it is very difficult the inherit all the desirable characters in one variety although efforts are being made in this direction. Such type of variability in the yield attributing characters in the small millets have been reported by many research Yang and Zhang (2006), Kamara *et al.* (2009) Bashir *et al.* (2015).

The 15th July sowing resulted in significantly higher yield attributes over the remaining date of sowing. The number of panicles was 223.03/m$_{2,}$ grains/panicle was 217.21, panicle length 23.92 cm, grains weight/panicle 0.0.65 g and 1000 grains weight 2.66 g due to timely sowing. This might be attributed to the maximum increase in growth parameter including number of leaves/plant due to applied date of sowing. Increased photosynthetic surface (leaves) brought about increased production of photosynthates and thereby increased translocation of photosynthates from source to the sink (Kamara *et al.*, 2009 and_Patel and Patel, 2002).

Productivity parameters

The grain and straw yields were secured maximum from kodo millet i.e. 17.75 q/ha,. However, the harvest index was in the higher range (30.67%). The second best millet was little millet producing 11.63 q/ha grain and 27.32 q/ha straw with 29.88% harvest index. The lower 25.47 q/ha straw yield, 29.69 % harvest index. Barnyard millet was found lowest producer of grain and straw. The higher productivity in case of kodo millet might be owing to increased number of panicles/m^2, the main yield attributing character. The increased yields due to increased yield attributing characters have also been reported by Hawlader and Islam (1991) and Dubey *et al.* (1993).

The 15th July sowing date proved significantly superior to other dates in respect to grain and straw yields of small millet. The 15 July sowing resulted in highest grain and straw yield i.e. 14.92 and 32.26 q/ha, respectively, being higher by 11.12 and 29.32 q/ha, respectively over 30th July sowing. The highest yield parameters due to timely sowing might be owing to the highest yield attributing parameters. The present results agree with those of other workers. (Dubey *et al.* 1993) Kamara *et al.* (2009), Ali and Squire (2002) Bashir *et al*. (2015) and Patel and Patel (2002) respectively).

Table 1. Growth, yield-attributes, yield and economics of small millets under different dates of sowing

Treatments	Plant height (cm)	Tillers/ m^2	Leaves/ plant	Panicles/ m^2	Grains/ panicle	Panicle length (cm)	Weight of grains/ panicle (g)	Test weight of 1000 grains (g)	Grain yield (q/ha)	Straw yield (q/ha)	Harvest index (%)	Net income (Rs/ha)	B:C ratio
Small millets													
Kodo	72.1	241	18.8	240	187	20.5	0.71	3.61	17.75	39.66	30.67	33962	2.45
Little	94.6	211	16.2	210	234	23.4	0.55	2.07	11.63	27.32	29.88	15626	1.71
Barnyard	109.1	182	16.1	182	203	24.7	0.56	2.02	10.16	25.47	28.69	10849	1.49
C.D.(P=0.05)	**4.34**	10.2	1.2	10.2	12.0	0.86	0.07	**0.25**	**1.72**	**3.63**	**NS**	--	--
Dates of sowing													
1st July	92.2	214	17.5	213	210	22.9	0.62	2.55	13.50	30.87	30.28	20667	1.45
15th July	97.3	221	17.5	221	217	23.9	0.65	2.66	14.92	32.26	31.53	25215	1.71
30th July	86.2	199	16.1	199	196	21.6	0.55	2.48	11.12	29.32	27.43	10724	1.49
C.D.(P=0.05)	**4.34**	**10.2**	**1.2**	**10.2**	**12.0**	**0.86**	**0.07**	**NS**	**1.72**	**NS**	**2.20**	--	--
Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**Sig.**	**NS**	**Sig.**	**Sig.**	**Ns**	--	--

Economical gain

Out of three small millet under study, kodo millet took a lead with respect to economical gain. The maximum net income from this kodo millet was up to Rs. 33962/ha with B: C ratio 2.449. The second best variety was little millet giving net income up to Rs. 15626/ha with B:C ratio 1.709. The lowest net income (Rs. 10849/ha) and B:C ratio (1.489) were obtained from barnyard millet. This was eventual as the net income is directly positively correlated with the grain and straw yields per hectare from those varieties.

Under 15th July sowing date, the net income was highest up to Rs. 25215/ha with B:C ratio 1.71. It was higher by Rs. 2667/ha over 1st July sowing. This was owing to highest grain and straw yields from 15th July sowing which filched higher market value. The economical gain was further aggravated when kodo millet was sown on 15th July. This was eventually due to increased production of grain and straw from both these interactions.

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