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Enhancing productivity of summer sesame (*Sesamum indicum*) on paddy fallows through optimization of fertilizer, planting geometry and genotypes

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ABSTRACT

A field experiment was conducted during summer 2007 and 2008 at ARS, Mugad, Karnataka on paddy fallows to study the response of sesame (*Sesamum indicum* L.) genotypes to levels of fertilizer and planting geometry. Of the three cultivars, DS 1 and E 8 were comparable (1 200 and 1 164 kg/ha seeds, respectively) and were superior to DSS 9 (944 kg/ha) both in terms of seed yield and income, while increasing dose of fertilizer had no significant influence on any of the parameters studied. Higher population with 30/40 cm × 10 cm recorded higher seed yield and net income compared to 30/40 cm × 20 cm planting geometries. Among all, cultivar DS 1 recorded significantly higher seed yield (1 393 kg/ha) with recommended NPK (40:25:25 kg/ha, respectively) and spacing (30 cm × 10 cm). At 150 % recommended NPK and 45 cm × 10 cm spacing DS 1recorded higher N uptake (86.16 kg/ha) than cv. E 8 receiving recommended NPK and spacing (77.26 kg/ha). P uptake was also higher in same genotype and fertilizer level with 30 cm × 20 cm spacing (4.38 kg/ha) over cv. DSS 9 receiving recommended NPK and spacing. DS 1 with closer spacing of 30 cm × 10 cm and 100% NPK recorded significantly higher net returns and B:C ratio (₹ 43 268 and 4.48, respectively).

Key words: Economics, Genotype, Nutrient level, Seed quality, Spacing, Uptake, Yield

Sesame (*Sesamum indicum* L.), also known as til or gingilly, is the world's oldest spice and oilseed crop mainly grown for its seeds that contain approximately 50 per cent oil and 25 per cent protein. Sesame seeds are rich source of food, nutrition, edible oil, health care and bio-medicine. Sesame oil has excellent nutritional, medicinal, cosmetic and cooking qualities for which it is known as 'the queen of oils' in the West and in Tamil as '*nallennai*' meaning good oil. Due to the presence of potent antioxidants (sesamum, sesamolin and sesamol) the oil is one of the most stable oils in the world. Sesame seeds are called as 'the seeds of immortality'. Because of these attributes sesame acquired global demand and presently India stands next only to China in production and export.

Exports being on the rise ensuring good returns to farmers nevertheless warrant production of quality seeds. Since the *kharif* crop is often caught in rains at maturity resulting in discoloured grains due to mould incidence fail to attract export market. On the other hand, summer produce is disease free with good quality seeds of attractive colour. Besides, yield potential of crop during summer is also high and paddy fallows offer ideal venues for the crop as water during summer is not enough for growing many other economic crops in the hilly and transitional zones of Karnataka. However, it necessitates identification of suitable cultivar as a cultivar performing better during rainy season may not do well in other seasons of the year (Dixit *et al.* 1997). And, crop being energy rich, also needs adequate nutrition for realization of its potential. Besides, optimum plant stand is another crucial factor in maximization of production particularly in paddy fallows as soil physical condition is often a limitation in crop establishment itself. Therefore, a study was undertaken to maximize the yield of sesame through genotypic selection and optimization of population and nutrient supply during summer on paddy fallows at Agricultural Research Station, Mugad, Karnataka.

MATERIALS AND METHODS

The experiment was conducted on paddy fallows at Agricultural Research Station, Mugad (15°15' N latitude, 70°40' E longitude and an altitude of 697 m above mean sea level) falling in the Northern Transition Zone (Zone-8) of Karnataka which lies between Hilly zone (Zone-9) towards West and Northern Dry Zone (Zone-3) towards East. The soil was sandy loam in texture, neutral in reaction (pH 6.75), with medium organic carbon (0.63 kg/Mg), medium

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soil available nitrogen (288 kg/ha) and phosphorus (29 kg/ha) and high available potassium (360 kg/ha).

The experiment was laid out in a split plot design with two fertilizer levels, viz. RDF (40:25:25 kg/ha, respectively) and 150% recommended NPK as main plots through urea, Diammonium phosphate and Muriate of potash, three genotypes, viz. DS 1, E 8 and DSS 9 as sub plots and four planting geometries, viz. S_1: 30 cm × 10 cm (333 333 plants/ha), S_2: 30 cm × 20 cm (166 666 plants/ha), S_3: 45 cm × 10 cm (222 222 plants/ha) and S_4: 45 cm × 20 cm (111 111 plants/ha) as sub sub plots. Seeds of DS 1 and E 8 were obtained from the AICRP on oil seeds centre of Main Research Station, UAS, Dharwad. Seeds of DSS 9 were obtained from Department of Genetics and Plant Breeding, College of Agriculture, Dharwad. Crop was sown on 20 and 26, February 2007 and 2008, respectively. Before sowing seeds were treated with *Trichoderma*, a biopesticide @ 3-4 g/kg to control soil borne pathogens. Later seeds were hand placed in furrows maintaining spacing as per treatment. Crop was supplied with a light protective irrigation at 30 and 60 days after sowing (DAS). Nitrogen was applied in two splits; 50 per cent of the dosage at the time of sowing along with entire quantity of phosphorus and potassium and remaining nitrogen was top dressed 25 DAS. Biometric observations on crop, seed quality, yield, and plant nutrient uptake, and economics were subjected for statistical analysis. Factor effects and interaction of higher order are discussed.

RESULTS AND DISCUSSION

Effect of fertilizer levels

Significant influence of higher level of fertilizer over recommended level on leaf area index was visible at peak crop growth (Table 1). However, increased application of fertilizer had no significant influence on total dry matter production (TDMP), number of capsules, seed weight per plant, seed and stalk yields, harvest index, oil and protein contents, gross and net returns, and B:C ratio (Table 1 and 2), whereas, nutrient uptake differed significantly due to fertilizer levels. Application of 150% recommended NPK recorded significantly higher nutrient uptake (84.48, 4.38 and 27.01 kg/ha NPK, respectively) over application of recommended NPK (79.54, 3.81 and 24.84 kg/ha NPK, respectively, Table 2). The higher initial soil nutrient status and moderate level of soil organic carbon after rainy season paddy probably were sufficient enough to meet the crop nutritional requirement and hence there was no response to additional fertilization in any conspicuous way in sesame.

Performance of genotypes

Cultivars DS 1 and E 8 were at par in seed yields (1 200 and 1 164 kg/ha seeds, respectively) and both were significantly superior to the newly developed genotype DSS 9 (Table 1). The improvement in yield with DS 1 over DSS 9 was to the tune of 27%. Such yield differences in the performances of genotypes were reported earlier by Channabasavanna and Shetty (1992) and Basavaraj *et al*. (2000) during summer in the Tunga Bhadra Project command of Karnataka. Similarly, Dixit *et al*. (1997) reported differences in varietal performances.

Improved performance in DS 1 could be traced back to variations in yield attributes. Seed weight per plant in DS 1 (5.02 g) was significantly higher than in DSS 9 (4.57 g) (Table 1).This is in conformity with Ghungarde *et al*. (1992) and Kanabur (1998). Further, number of capsules was more in DS 1 (27/plant) than in DSS 9 (24.7/plant). Dixit *et al*. (1997) opined that in sesame plants number of capsules/plant is an important yield attribute with direct bearing on yield and it varies significantly in response to change in climatic conditions.

Differences in seed yield and yield components could

Table 1 Growth and yield attributes, yield and harvest index of sesame as influenced by of genotype, fertilizer level and spacing

Treatment		LAI at 60 DAS	TDM (g/plant)	Capsules/ plant	Seed weight (g/plant)	Seed yield (kg/ha)	Stalk yield (kg/ha)	Harvest index
Genotype	DS 1	3.10	20.61	26.8	5.02	1 200	3 147	0.280
	E 8	3.07	18.51	24.7	4.85	1 164	2 662	0.308
	DSS 9	3.00	18.29	24.7	4.57	944	3 040	0.241
	S Em±	0.03	0.26	0.31	0.10	20	64	0.006
	CD 0.05	NS	0.84	1.03	0.34	71	208	0.021
$N:P_2O_5:K_2O$ (kg/ha)	40:25:25	2.98	19.18	25.2	4.93	1 097	2 934	0.277
	60:37:37	3.13	19.08	25.6	4.70	1 108	2 874	0.275
	S Em±	0.03	0.32	0.22	0.10	19	18	0.003
	CD 0.05	0.10	NS	0.69	NS	NS	NS	NS
Spacing (cm × cm)	30 × 10	3.00	18.46	22.7	4.65	1 182	3 033	0.280
	30 × 20	3.14	18.82	24.8	4.64	1 030	2 842	0.269
	45 × 10	2.99	19.27	26.9	4.99	1 153	2 989	0.280
	45 × 20	3.10	20.00	27.2	4.99	1 044	2 853	0.276
	S Em±	0.01	0.17	0.40	0.11	28	73	0.011
	CD (P=0.05)	0.03	0.48	1.15	0.32	80	210	NS

LAI, Leaf area index, DAS, days after sowing, TDM, total dry matter, NS, not significant

Table 2 Protein and oil contents (%), nutrient uptake (kg/ha), returns (₹/ha) and B:C ratio of sesame as influenced by of genotype, fertilizer level and spacing

Treatment		Protein (%)	Oil (%)	Nutrient uptake (kg/ha)			Returns (Rs/ha)		B:C
				N	P	K	Gross	Net	
Genotype	DS 1	25.10	47.26	82.42	4.09	25.91	47 980	35 300	3.79
	E 8	25.35	47.83	81.94	4.16	25.50	46 560	33 880	3.67
	DSS 9	24.89	47.43	81.67	4.05	26.36	37 760	25 080	2.98
	SEm±	0.19	0.10	0.57	0.05	0.35	812	812	0.06
	CD 0.05	NS	0.31	NS	NS	NS	2 648	2 648	0.21
$N:P_2O_5:K_2O$ (kg/ha)	40:25:25	25.42	47.39	79.54	3.81	24.84	43 907	31 448	3.54
	60:37:37	24.81	47.62	84.48	4.38	27.01	44 290	31 352	3.42
	SEm±	0.09	0.59	0.67	0.09	0.39	867	867	0.07
	CD 0.05	0.27	NS	2.05	0.52	1.17	NS	NS	NS
Spacing (cm × cm)	30 × 10	25.44	47.51	80.10	3.97	25.24	47 300	34 590	3.73
	30 × 20	24.92	47.43	83.24	4.16	26.25	41 190	28 530	3.25
	45 × 10	25.02	47.42	81.58	4.09	25.95	46 130	33 430	3.63
	45 × 20	25.06	47.67	83.12	4.16	26.26	41 770	29 120	3.30
	SEm±	0.09	0.59	0.65	0.06	0.37	1 128	1 148	0.09
	CD (P=0.05)	0.27	NS	1.86	0.17	NS	3 235	3 744	0.30

NS, Not significant

also be traced back to differences in TDMP. DS 1 recorded higher TDMP (20.61 g) than DSS 9 (18.29 g, Table 1). Similar results were reported earlier by Tomar *et al*. (1992) and Kanabur (1998). Genotype DS 1 recorded higher LAI (3.10 at 60 DAS) throughout life cycle compared to E 8 (3.00) and DSS 9 (3.07) particularly at later stages which is more important with regard to sink size.

As far quality of seed was concerned, the oil content did not vary significantly among the genotypes (47.83, 47.43 and 47.26 % with E 8, DSS 9 and DS 1, respectively) and so was seed protein content (24.89, 25.35 and 25.10 %, respectively with DSS 9, E 8 and DS 1, Table 2).

Consequent upon higher seed yield, DS 1 recorded higher gross and net income and benefit: cost ratio (₹ 47980 35300/ha and 3.79, respectively). E 8 was comparable (Table 2).

Spacing/population

Seed yields averaged over genotypes and fertilizer were higher with higher population of 333 333 plants/ha with 30 cm × 10 cm geometry (1 182 kg/ha) compared to lower population of 111 111 plants/ha with 45 cm × 20 cm spacing (1 044 kg/ha) (Table 1). Plants exhibited plasticity to spacing up to 171 000 plants/ha wherein spacing of 45 cm × 10 cm (1 153 kg/ha) was at par with 333 333 plants/ha. Any further reduction in population resulted in yield reduction in consonance with population though there was improvement in individual plant performance. The yield with former treatment was higher by 13.65 percent over wider spacing. Menon (1967) and Singh and Nema (1972) stressed need for closer spacing and higher seed rate. Majumdar and Roy (1992) and Gosh and Patra (1994) reported best yields with the population of 3.3 lakh/ha. Sharma *et al*. (1996) considered the population of 3.0 to 4.5 lakh plants/ha as optimum.

Interestingly, individual plant yield or any of the yield components failed to follow this trend. The per plant seed weight, number of capsules/plant, seed yield/capsule were higher with wider spacing of 45 cm × 20 cm (Table 1 and 2). Wider row spacing of 45 cm was superior to closer spacing of 30 cm. Higher seed weight/plant was recorded with 45 cm row spacing (4.99 g) as against 30 cm rows (4.65 and 4.64 g/plant, with 10 and 20 cm intra row spacing, respectively). Similarly, Majumdar and Roy (1992) observed superior performance of yield parameters at lower population levels. However, improvement in yield with increase in population in the present study could be attributed to compensation of branches by the number of plants per unit area which in turn could be due to contribution of main stem against that of branches (Narayanan and Narayanan 1987). In other words, besides seed weight/capsule, it is number of capsules/metre length is more important than number of capsules/plant in plastic crop like sesame.

Similar were the performances of growth components. The total dry matter production was higher with wider rows of 45 cm × 20 or 10 cm (19.27 and 20.00 g/plant, respectively) (Table 1). The reason for superior performance of individual plants could be due to red/far red light ratio under adequate soil water and nutrient supply. Plants grown in low populations received a higher red/far red light ratio compared with denser populations which caused a greater proportion of vegetative dry matter to be partitioned in to branches (Kasperbauer 1987).

The improved performance of individual plants, however, failed to compensate the reduction in population. This in turn could be attributed to limited plasticity of sesame within the range of populations studied. Consequently, higher total population in 30 cm × 10 cm spacing (conventional recommendation) helped to achieve higher productivity. In other words, had individual plant performance compensated the population reduction then performance of different populations used in the study could have been at parity, which was not the case.

Oil content did not differ significantly with different spacings/populations. Similarly, Srinivas *et al*. (1991) did not observe any significant change in proximate composition due variation in population. Oil yield, mostly, followed seed yield.

Genotype × spacing × nutrition

DS 1 receiving 100 % NPK and spacing of 30 cm × 10 cm (333 333 plants/ha) recorded significantly higher seed yield (1 393 kg/ha) which was higher by 12 per cent over the recommended genotype E 8 receiving 150% NPK with 30 cm × 10 cm spacing (1 241 kg/ha) while, lower yield was recorded with DSS 9 receiving recommended fertilizer and 30 cm × 20 cm spacing (812 kg/ha) (Fig 1). The former treatment also had higher stalk yield (3 308 kg/ha) which was higher by 9.50 percent over DSS 9 with 150 % NPK and 30 cm × 10 cm spacing (3 128 kg/ha) (Table 3).

As discussed in earlier sections, the higher seed yield and income are not solely due to superior performance of individual plants with respect to yield or growth components but were primarily due to higher population level used particularly in DS 1. DS 1 with 150% NPK and 45 cm × 20 cm spacing recorded higher seed weight (5.84 g/plant) over DSS 9 irrespective of fertilizer and spacing provided. This in turn was due to higher number of capsules per plant and seed yield per plant. DS 1 with recommended NPK and 30 cm × 20 cm and 45 cm × 20 cm recorded more number of capsules (24.7 and 31.5/plant) while, DSS 9 with similar fertilizer and spacing recorded lower number of capsules (21.5/plant) (Table 3).

As far growth was concerned DS 1 with 150% NPK and 45 cm × 10 cm produced higher TDMP (20.61 g/plant) while, lower TDMP was recorded with E 8 at recommended NPK and 150 % NPK and 30 cm × 10 and 20 cm (17.58 and 17.34 g/plant) (Table 3). The important aspect was the active photosynthetic area. DS 1 with 150% NPK and 30 cm × 20 cm spacing recorded higher leaf area index (3.26) over DSS 9 and E 8 at 60 DAS, i e at peak growing period. This particular behaviour is of significance as it helped DS 1 to outperform all genotypes at recommended as well

Table 3 Growth and yield attributes, yield and harvest index, nutrient uptake and economics of sesame as influenced by interaction due to genotype, fertilizer level and spacing

	LAI at 60 DAS	TDM (g/plant)	Capsules/ plant	Stalk yield (kg/ha)	Harvest index	Protein (%)	Oil (%)	Nutrient uptake (kg/ha)			Returns (₹/ha)		B:C
								N	P	K	Gross	Net	
$G_1F_1S_1$	2.91	19.87	22.8	3300	0.297	25.99	46.73	78.18	3.67	23.83	55 710	43 268	4.48
$G_1F_1S_2$	3.15	20.98	24.7	2961	0.276	25.31	47.70	81.51	3.92	24.22	44 880	32 481	3.62
$G_1F_1S_3$	2.83	19.93	29.2	3211	0.293	25.20	47.70	79.52	3.81	25.46	53 220	40 775	4.28
$G_1F_1S_4$	3.12	21.30	31.5	2737	0.290	25.13	45.85	82.70	3.92	25.54	44 780	32 392	3.61
$G_1F_2S_1$	3.12	20.18	23.5	3308	0.289	24.42	48.10	84.12	4.15	27.59	53 860	40 900	4.16
$G_1F_2S_2$	3.26	20.93	24.6	2997	0.255	24.68	46.87	86.16	4.39	26.61	41 060	28 140	3.18
$G_1F_2S_3$	3.11	20.36	29.5	3188	0.281	25.01	46.65	83.16	4.39	26.66	49 390	36 430	3.81
$G_1F_2S_4$	3.23	21.33	28.6	2932	0.259	25.04	48.48	84.06	4.38	27.39	40 910	28 000	3.17
$G_2F_1S_1$	2.91	17.82	22.0	2751	0.298	25.04	47.28	77.26	3.78	23.77	46 750	34 310	3.76
$G_2F_1S_2$	3.10	18.51	24.4	2712	0.299	25.13	47.27	80.06	3.93	25.61	44 660	32 256	3.60
$G_2F_1S_3$	2.90	18.82	24.9	2594	0.307	25.33	47.73	78.68	3.87	25.32	45 970	33 527	3.69
$G_2F_1S_4$	3.00	19.38	24.4	2512	0.305	25.78	48.08	80.89	3.83	25.11	43 930	31 540	3.55
$G_2F_2S_1$	3.15	17.41	23.2	2623	0.322	25.08	48.48	82.83	4.35	26.74	49 640	36 680	3.83
$G_1F_2S_2$	3.17	16.72	25.0	2547	0.313	25.11	48.58	85.89	4.58	27.17	46 230	33 300	3.58
$G_2F_2S_3$	3.16	19.52	27.2	2801	0.297	25.14	47.80	84.12	4.38	27.45	47 170	34 210	3.64
$G_2F_2S_4$	3.20	19.87	26.6	2562	0.321	25.18	47.42	85.78	4.53	26.86	48 120	35 210	3.73
$G_3F_1S_1$	2.87	17.58	21.5	3086	0.241	25.97	47.82	76.65	3.53	23.46	39 300	26 860	3.16
$G_3F_1S_2$	3.11	18.42	26.1	2774	0.232	25.08	47.13	80.92	3.72	24.43	32 470	20 070	2.62
$G_3F_1S_3$	2.87	18.73	24.9	2908	0.264	25.07	47.90	77.44	3.89	26.23	40 890	28 450	3.29
$G_3F_1S_4$	3.03	18.90	25.9	2938	0.226	24.96	47.48	80.64	3.87	27.08	34 330	21 930	2.77
$G_3F_2S_1$	3.06	17.88	23.4	3128	0.235	25.14	46.63	81.55	4.35	26.06	38 530	25 570	2.97
$G_3F_2S_2$	3.04	17.34	24.2	3062	0.236	24.23	47.02	84.91	4.45	27.43	37 840	24 920	2.93
$G_3F_2S_3$	3.03	18.26	25.5	3230	0.237	24.35	46.75	86.56	4.23	26.57	40 160	27 200	3.10
$G_3F_2S_4$	3.02	19.23	26.0	2835	0.254	24.29	48.70	84.67	4.44	27.61	38 570	25 660	2.99
SEm±	0.03	0.41	0.94	180	0.027	0.92	0.28	1.58	0.15	0.91	2 763	2 763	0.22
CD 0.05	0.07	1.18	2.80	515	0.074	NS	0.80	4.55	0.43	2.61	7 925	7 925	0.63

G_1 - DS 1, G_2 - E 8, G_3 - DSS 9, F_1 – 100% NPK (40:25:25 kg/ha, respectively), F_2 – 150% NPK, S_1 - 30 cm × 10 cm, S_2 - 30 cm × 20 cm, S_3 - 45 cm × 10 cm and S_4 - 45 cm × 20 cm; LAI, leaf area index; DAS, days after sowing; TDM, total dry matter; NS, not significant

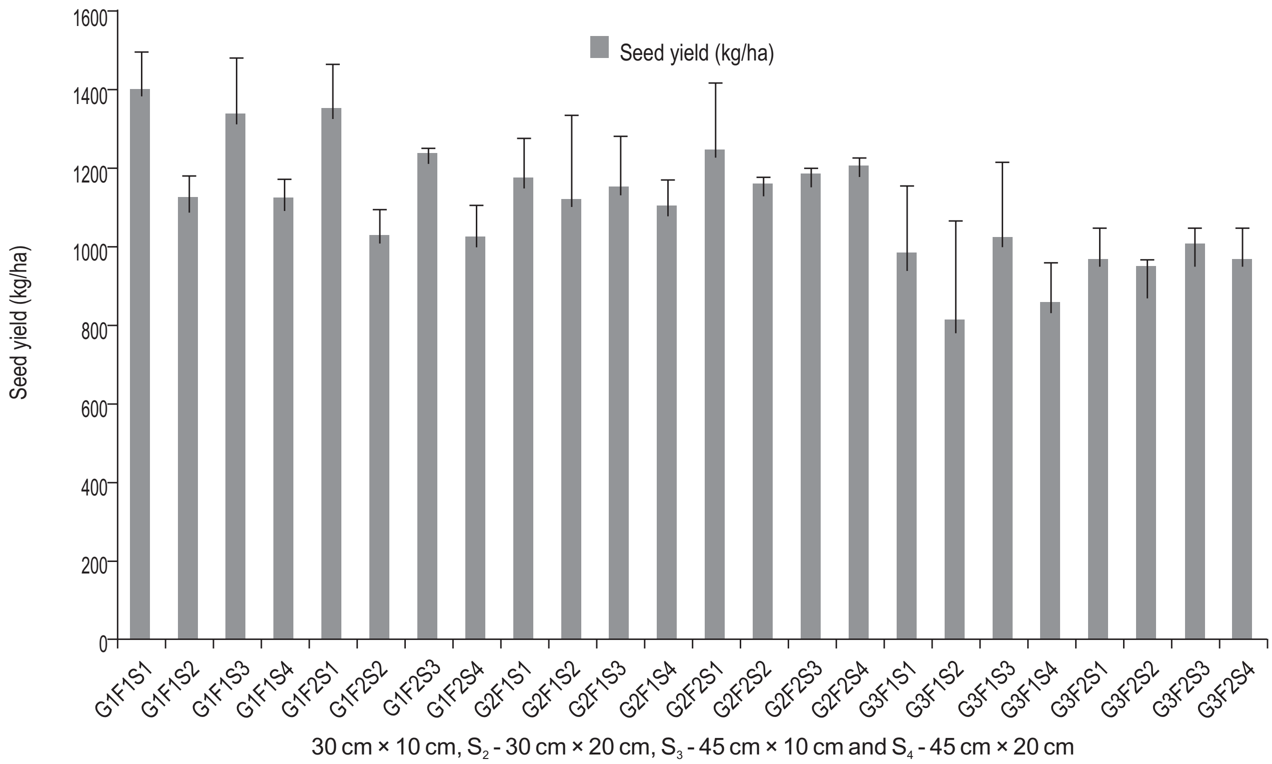

Fig 1 Seed yield of sesame as influenced by interaction due to genotype, fertilizer level and spacing

as at higher nutrition levels with recommended spacing/ population level.

Better performance of DS 1 with 150% NPK and 30 cm × 20 cm spacing with regard to seed yield or growth and yield components could be further related to higher N uptake (86.16 kg/ha) over E 8 with recommended NPK and spacing (77.26 kg/ha), but P uptake was higher in same genotype and fertilizer level with 30 cm × 20 cm spacing (4.45 kg/ha) over DSS 9 with recommended NPK and spacing (Table 3). Consequent upon higher N uptake, former treatment could accumulate higher dry matter besides partitioning more of it into seeds as evidenced from seed yield.

In all, DS 1 and E 8 are suited for summer cultivation in paddy fallows. Adoption of 30 cm × 10 cm (333 333 plants/ha) spacing and supply of 40:25:25 kg/ha NPK would help to obtain higher and sustained yield of good quality seeds.

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