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Effect of fertilizer levels and plant densities on growth, yield and economics of summer soybean (*Glycine max*. L. Merrill) for seed production

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Abstract
A field experiment was conducted to access "Effect of fertilizer levels and plant densities on growth and yield of summer soybean (*Glycine max*. L. Merrill) for seed production" at PG Research Farm, Agronomy Section, R.C.S.M. College of Agriculture, Kolhapur during summer 2017. The treatments consisting of three fertilizer levels (37.5:56.25:33.75 NPK kg ha^{-1} i.e. 75% of RDF, 50:75:45 NPK kg ha^{-1} i.e. 100% RDF and 62.5:93.75:56.25 NPK kg ha^{-1} i.e.125% RDF) and three plant densities [1,48,148 plants ha^{-1} (45 x 15 cm^2), 2,22,222 plants ha^{-1}(45 x 10 cm^2) and 4,44,444 plants ha^{-1}(45 x 5 cm^2)]. The results revealed that the application of 125% RDF recorded significantly higher growth parameters over rest of the treatments. The various yield attributes and seed yield were highest with application of 125% RDF (27.44 q ha^{-1}) followed by 100% RDF (25.99 q ha^{-1}). Significantly higher mean of growth parameters (except plant height) was recorded in Plant density 1, 48,148 plants ha^{-1} (45 x 15 cm^2) over rest of the plant densities. The plant density 4,44,444 plants ha^{-1} (45 x 5 cm^2) produced highest seed yield (27.94 q ha^{-1}) and it was followed by plant density 2,22,222 plants ha^{-1} (45 x 10 cm^2) (25.64 q ha^{-1}).

Keywords: fertilizer levels, plant densities, growth and yield of soybean

Introduction
Soybean (*Glycine max* (L.) Merrill) is well known leguminous crop and belongs to family leguminoceae. It has Eastern Asian origin. It is the miracle crop and has witnessed phenomenal growth in production, processing and trade in last few years in India and has revolutionized the rural economy and improved socio economic status of farmers. Soybean cultivation has placed India on the world map in recent past. Soybean has not only gained the vital importance in Indian agriculture, but also plays an important role in oil economy of India, However, the national production of soybean has not been able to meet its domestic requirements due to poor average yield. Among the various factors responsible for poor yield of soybean, inadequate supply of plant nutrients is the most important. Good seed yield can be achieved by balanced nutrition. More scientific effort needed to increase the productivity of soybean per unit area, and per unit time with optimum plant population. It is necessary to maintain optimum plant population to get higher productivity. Application of NPK fertilizers increase growth attributes as well as seed yield and seed quality of soybean. The present investigation was undertaken to find out optimum dose of NPK nutrient and plant density for soybean.

Materials and Methods
An experiment to study Performance of summer soybean (*Glycine max*. L. Merrill) to fertilizer levels and plant densities for seed production was conducted at PG Research Farm, Agronomy Section, College of Agriculture, Kolhapur during summer 2017. The soil of the experimental plot was clayey in texture, low in available nitrogen (207.00 kg ha^{-1}), medium in available phosphorus (28.70 kg ha^{-1}) and high in available potassium (287.00 kg ha^{-1}). The soil was slightly alkaline in reaction (pH 7.75). The experiment was laid out in randomized block design (Factorial) with three replications. There were nine treatment combinations, three fertilizer levels (37.5:56.25:33.75 NPK kg ha^{-1} i.e. 75% RDF, 50:75:45 NPK kg ha^{-1} i.e. 100% RDF and 62.5:93.75:56.25 NPK kg ha^{-1} i.e. 125% RDF) and three plant densities [1,48,148 plants ha^{-1} (45 x 15 cm^2), 2,22,222 plants ha^{-1}(45 x 10 cm^2) and 4,44,444 plants ha^{-1} (45 x 5 cm^2)]. The soybean seeds were treated with *Rhizobium* and PSB @ 250 g 10 kg^{-1} seed. Sowing was done with the help of marker at a distance of 45 cm

between the rows and 5, 10 and 15 cm spacing between the plants as per treatments. The seed was sown at 5 cm depth by dibbling. The quantity of nitrogen, phosphorus and potassium were applied as per treatments. The fertilizer was applied as a basal application by using urea, single super phosphate (SSP) and muriate of potash (MOP) as sources for nitrogen, phosphorus and potash respectively.

Results and Discussion

Effect on growth parameters

The growth attributes were influenced significantly due to application of different fertilizer levels. Application of 125% RDF recorded significantly higher growth attributes *viz*. plant height, number of branches plant^{-1}, plant spread plant^{-1} (cm), leaf area plant^{-1} (dm^2), dry matter plant^{-1} (g) over rest of the fertilizer levels and it was mainly due to higher availability nutrients. These results are in accordance with Singh *et al*. (1994) and Singh *et al.* (2006) [8].

The growth attributes were influenced significantly due to the effect of different plant densities. Plant density 1,48,148 plants ha^{-1} (45 x 15 cm^2) recorded significantly higher growth attributes *viz*., number of branches plant^{-1}, plant spread plant^{-1} (cm), leaf area plant^{-1} (dm^2), dry matter plant^{-1} (g) due to more availability of space for aeration, radiation, expansion and less competition for available nutrients, moisture and sunlight.. The plant height was significantly higher in plant density 4, 44, 444 plants ha^{-1} (45 x 5 cm^2) due to competition amongst plants for sunlight. Increasing plant density which increases plant height of soybean has been reported by Kang *et al*., (1998) [5]. These results are in accordance with Qayuum *et al*. (1983) [9], Goyal *et al*. (2008) [4] and Khazi *et al* (2013) [6].

Effect on yield attributes and yield

Application of 125% RDF recorded significantly highest number of pods plant^{-1}, highest seed yield plant^{-1} (g) and mean 100 seed weight over rest of the treatments. Application of 125% RDF recorded the maximum length of pods and higher number of seeds pod^{-1} which was significantly superior over 75% RDF and on par with 100% RDF. Application of 125% RDF (27.44 q ha^{-1}) recorded the maximum seed yield, which was significantly superior over 75% RDF (23.90 q ha^{-1}), while it was on par with 100% RDF (25.99 q ha^{-1}). Application of 125% RDF recorded maximum straw yield (46.19 q ha^{-1}), biological yield (73.63 q ha^{-1}) and harvest index which was significantly superior over rest of the fertilizer levels. These results are in accordance with Ahmad *et al.* (2004) [1] and Singh *et al*. (2006) [8].

The plant density 1,48,148 plants ha^{-1} (45 x 15 cm^2) recorded highest number of pods plant^{-1} and it was significantly superior over plant density 4,44,444 plants ha^{-1} (45 x 5 cm^2) and on par with plant density 2,22,222 plants ha^{-1} (45 x 10 cm^2). Highest length of pod, number of seeds pod^{-1}, seed yield plant^{-1} and mean 100 seed weight was recorded with plant density 1,48,148 plants ha^{-1} (45 x 15 cm^2) which was significantly superior over rest of the treatments. Plant density 4,44,444 plants ha^{-1} (45 x 5 cm^2) recorded maximum seed yields (27.94 q ha^{-1}), straw yield (47.33 q ha^{-1}), biological yield (75.27 q ha^{-1}) which was significantly superior over rest the treatments. Higher seed yield at highest plant population level was due to more pods per unit area. Seed yield is positively related to photosynthetically active radiation (PAR) interception (De bruin and Pedersen, 2009) [3]. Therefore, at higher plant population more interception of PAR is expected to increase seed yield and this could be the reason for higher yield at higher plant population in the present study. Highest harvest index was recorded at plant density 1,48,148 plants ha^{-1} (45 x 15 cm^2) followed by plant density 2,22,222 plants ha^{-1} (45 x 10 cm^2) and lowest harvest index was recorded at plant density 4,44,444 plants ha^{-1} (45 x 5 cm^2). These results are in accordance with Sarmah and kalita, (1982) [7], Balyan and Mehta (1985) [2] and Goyal *et al*. (2008) [4].

Effect on economics of soybean

The highest net monetary return and B:C ratio were recorded at 125% RDF followed 100% RDF. 75% RDF recorded lowest net monetary return and B:C ratio. Here the benefit cost ratio increases with increasing fertilizer level up to 100% RDF thereafter, B:C ratio increases at decreasing rate. The highest net monetary return and B:C ratio recorded by at plant density 4, 44, 444 plants ha^{-1} (45 x 5 cm^2) followed by plant density 2, 22, 222 plants ha^{-1} (45 x 10 cm^2). Plant density 1, 48, 148 plants ha^{-1} (45 x 15 cm^2) recorded net monetary return and B:C ratio. Here the B:C ratio increases with increasing plant density.

Table: 1 Effect of fertilizer levels and plant densities on growth parameters of soybean

Treatments	Plant height (cm)	Number of branches plant^{-1}	Plant spread (cm)	Leaf area (dm^2)	Dry matter plant^{-1} (g)
Fertilizer level (N:P_2O_5:K_2O Kg ha^{-1}) (F)					
F_1 - 75% RDF (37.5: 56.25: 33.75)	55.85	4.69	43.23	77.90	21.92
F_2 - 100% RDF (50: 75: 45)	59.75	4.91	45.51	81.04	23.55
F_3 - 125% RDF (62.5: 93.75: 56.25)	62.98	5.23	47.98	83.11	25.05
S.E m±	0.54	0.07	0.36	0.50	0.37
C.D.at 5%	1.63	0.21	1.09	1.49	1.12
Plant Density (D)					
D_1 - 1,48,148 plants ha^{-1} (45 cm x 15 cm)	56.32	5.63	49.17	83.96	26.83
D_2 - 2,22,222 plants ha^{-1} (45 cm x 10 cm)	59.47	4.89	45.79	80.66	23.39
D_3 - 4,44,444 plants ha^{-1} (45 cm x 5 cm)	62.41	4.30	41.76	76.89	20.32
S.E m±	0.54	0.07	0.36	0.50	0.37
C.D.at 5%	1.63	0.21	1.09	1.49	1.12
Interaction (F x D)					
S.E m±	0.96	0.12	0.63	0.86	0.81
C.D.at 5%	NS	NS	NS	NS	NS
General mean	59.53	4.94	45.57	80.68	23.51

Table 2: Effect of fertilizer levels and plant densities on yield attributing characters of soybean

Treatments	No. of pods plant $^{-1}$	Length of pod (cm)	No. of seeds pod^{-1}	Seed yield plant^{-1} (g)	100 seed weight (g)
Fertilizer level (N:P_2O_5:K_2O Kg ha^{-1}) (F)					
F_1 - 75% RDF (37.5: 56.25: 33.75)	64.56	2.78	2.67	18.41	13.08
F_2 - 100% RDF (50: 75: 45)	67.07	2.89	2.82	20.60	13.53
F_3 - 125% RDF (62.5: 93.75: 56.25)	68.38	2.98	2.92	22.45	14.05
S.E m±	0.43	0.04	0.05	0.33	0.07
C.D.at 5%	1.30	0.12	0.16	0.99	0.22
Plant Density (D)					
D_1 - 1,48,148 plants ha^{-1} (45 cm x 15 cm)	67.75	3.00	3.02	22.20	14.02
D_2 - 2,22,222 plants ha^{-1} (45 cm x 10 cm)	66.79	2.86	2.78	20.18	13.49
D_3 - 4,44,444 plants ha^{-1} (45 cm x 5 cm)	65.46	2.77	2.60	19.11	13.14
S.E m±	0.43	0.04	0.05	0.33	0.07
C.D.at 5%	1.30	0.12	0.16	0.99	0.22
Interaction (F x D)					
S.E m±	0.75	0.07	0.09	0.57	0.13
C.D.at 5%	NS	NS	NS	NS	NS
General mean	66.67	2.88	2.80	20.49	13.55

Table 3: Effect of fertilizer levels and plant densities on yield, harvest index and economics of soybean

Treatments	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)	Net monitory return (Rs)	B:C ratio
Fertilizer level (N:P_2O_5:K_2O Kg ha^{-1}) (F)						
F_1 - 75% RDF (37.5: 56.25: 33.75)	23.90	35.69	59.59	40.76	32908	1:1.60
F_2 - 100% RDF (50: 75: 45)	25.99	42.02	68.01	38.61	40270	1:1.72
F_3 - 125% RDF (62.5: 93.75: 56.25)	27.44	46.19	73.63	37.55	45448	1:1.80
S.E m±	0.49	0.58	1.07	-	-	-
C.D.at 5%	1.49	1.74	3.23	-	-	-
Plant Density (D)						
D_1 - 1,48,148 plants ha^{-1} (45 cm x 15 cm)	23.77	34.11	57.88	41.06	36053	1:1.65
D_2 - 2,22,222 plants ha^{-1} (45 cm x 10 cm)	25.64	42.44	68.08	37.66	42642	1:1.76
D_3 - 4,44,444 plants ha^{-1} (45 cm x 5 cm)	27.94	47.33	75.27	37.11	50479	1:1.88
S.E m±	0.49	0.58	1.07	-	-	-
C.D.at 5%	1.49	1.74	3.23	-	-	-
Interaction (F x D)						
S.E m±	0.86	1.00	1.86	-	-	-
C.D.at 5%	NS	NS	NS	-	-	-
General mean	25.78	41.30	67.08	38.97	-	-

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