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Influence of fertilizer levels and plant densities on nutrient uptake, yield and soil properties of summer soybean (*Glycine max*. L. Merrill)

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Abstract
A field experiment entitled, "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, R.C.S.M. College of Agriculture, Kolhapur during summer 2017 to evaluate different treatments on nutrient status and soil properties. The treatments consisting of 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)]. Mean N, P and K content in seed and straw, total uptake of N, P and K and available N, P and K was influenced significantly by different fertilizer level as well as plant densities. The mean N, P and K content, total N, P and K uptake and available N, P and K were maximum with application of 125% RDF followed by 100% RDF. Mean N, P and K content in seed and straw was recorded highest in, 48,148 plants ha^{-1} (45 x 15 cm^2) followed by 2,22, 222 plants ha^{-1} (45 x 10 cm^2) The uptake of N, P and K in soybean was highest in plant density 4,44,444 plants ha^{-1} (45 x 5 cm^2) followed by 2,22, 222 plants ha^{-1}(45 x 10 cm^2). Numerically available NPK in soil was increased with increase in fertilizer levels. It was higher at 125% RDF than fertilizer level 100% RDF. Highest available N, P and K was recorded highest in 1, 48, 148 plants ha^{-1} (45 x 15 cm^2) followed by 2, 22, 222 plants ha^{-1}(45 x 10 cm^2). The seed yield were highest with application of 125% RDF (27.44 q ha^{-1}) followed by 100% RDF (25.99 q ha^{-1}). 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}). Protein content and oil content in seeds of soybean was significantly highest in125% RDF and in 1, 48, 148 plants ha^{-1} (45 x 15 cm^2) treatment.

Keywords: fertilizer levels, plant densities, NPK content, uptake, soybean

Introduction
Soybean (*Glycine max* (L.) Merrill) is known as leguminous crop and belongs to family leguminoceae. 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. Therefore, the present investigation was undertaken to study Performance of summer soybean (G*lycine max*. L. Merrill) to fertilizer levels and plant densities for seed production and its effect on nutrient content, uptake, soil status and yield of 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, R.C.S.M. 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 gross and net plot size were 5.4 m x 4.5 m and 4.8 m x 3.6 m, respectively. 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 murate of potash (MOP) as sources for nitrogen, phosphorus and potash respectively.

Results and Discussion

Effect on NPK content in seed and straw

Different fertilizer level has significant effect on NPK content in seed and straw. Application of 125 % of RDF recorded significantly higher NPK content in seed and straw over application of 75 % of RDF. However treatment 125 % of RDF was at par with 100 % of RDF in case of NPK content in seed and N content in straw. Similar results was reported by Dwivedi *et al.* (1996) [2].

Different plant density has significant effect on NPK content in seed and straw. Plant density 1,48,1 48 plants ha-1 (45 x 15 cm2) recorded significantly higher NPK content in seed and straw over application of 75 % of RDF. However treatment 125 % of RDF was at par with 100 % of RDF in case of NPK content in seed and N content in straw. Similar results was also reported by Rajput *et al.* (1985) [12].

Effect on NPK uptake

NPK uptake kg $ha^{-1}$was increased with increase in fertilizer levels. NPK uptake kg $ha^{-1}$was significantly highest at 125% RDF over rest of the treatments, similarly NPK uptake kg ha^{-1} at 100% RDF was significantly higher over 75% RDF. Similar results were also reported by Kumar and Rao (1991).

NPK uptake kg $ha^{-1}$was increased with increase in plant density it was significantly higher at plant density 4,44,444 plants ha^{-1} (45 x 5 cm^2) over rest of the treatment, similarly NPK uptake kg ha^{-1}at plant density 2,22, 222 plants ha^{-1} (45 x 10 cm^2) was significantly higher over plant density 1,48,148 plants ha^{-1} (45 x 15 cm^2). Similar result was also reported by Khazi *et al.* (2013) [6].

Effect on available NPK in soil

Different fertilizer levels had no significant effect on available NPK. Numerically available NPK was increased with increase in fertilizer levels. It was higher at 125% RDF than fertilizer level 100% RDF. Similar result was reported by Naidu and Pillai (1991).

Plant densities had no significant effect on available NPK. Numerically higher available NPK was found in 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). This was probably due to the more competition for these nutrient leads to higher extraction of nutrients. Similar result was also reported by Khazi *et al.* (2013) [6].

Protein content in Seed (%)

Protein content was increased with increase in fertilizer levels. It was highest at 125% RDF. Protein content was significantly highest at 125% RDF over 75% RDF and on par with 100% RDF. Lowest protein content was recorded in fertilizer level 75% RDF this was probably due to less uptake of nitrogen at lower nitrogen level. Similar results was also reported by Kausadikar *et al.* (2003) [5].

Protein content was decreases with increase in plant density. It was highest in 1,48,148 plants ha^{-1} (45 x 15 cm^2) which was significantly highest 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). Lowest protein content was recorded in plant density 4, 44, 444 plants ha^{-1} (45 x 5 cm^2) this was due to more competition for N uptake in higher plant density leads to lower protein content at higher plant density.

Effect on oil content in seed (%)

Oil content was increased with increase in fertilizer levels. Oil content was significantly highest at 125% RDF over 75% RDF and on par with 100% RDF, similarly 100% RDF was on par with 75% RDF. Increases in oil content might be attributed to balanced nutrition seems to be involved in an increased conversion of primary fatty acid metabolites to end products of fatty acid resulting in higher oil content in seeds. Similar results was also reported by Halvankar *et al.* (1999) [4].

Oil content was decreases with increase in plant density. Oil content was significantly highest at plant density 1,48,148 plants ha^{-1} (45 x 15 cm^2) over rest of the treatments, similarly plant density 2,22, 222 plants ha^{-1} (45 x 10 cm^2) was on par with plant density 4,44,444 plants ha^{-1} (45 x 5 cm^2). This might be attributed to less competition for nutrition seems to be involved in an increasing the rate of conversion of primary fatty acid metabolites to end products of fatty acid resulting in higher oil content in seeds.

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) and Singh *et al.* (2006) [11].

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). 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) [9], Balyan and Mehta (1985) [1] and Goyal *et al*. (2008) [3].

Table 1: NPK content in seed and straw of soybean as influenced by different treatments

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Seed	Straw	Seed	Straw	Seed	Straw
Fertilizer level ($N:P_2O_5:K_2O$ Kg ha^{-1}) (F)						
F_1 - 75 % RDF (37.5 : 56.25 : 33.75)	6.23	0.59	0.55	0.32	0.67	1.81
F_2 - 100 % RDF (50 : 75 : 45)	6.41	0.61	0.57	0.34	0.69	1.84
F_3 - 125 % RDF (62.5 : 93.75 : 56.25)	6.31	0.60	0.57	0.35	0.64	1.85
S.Em±	0.05	0.01	0.01	0.004	0.007	0.005
C.D.at 5%	0.15	0.02	0.02	0.01	0.02	0.01
Plant Density (D)						
D_1 - 1,48,148 plants ha^{-1} (45 cm x 15 cm)	6.29	0.62	0.57	0.34	0.71	1.85
D_2 - 2,22,222 plants ha^{-1} (45 cm x 10 cm)	6.41	0.60	0.57	0.34	0.68	1.84
D_3 - 4,44,444 plants ha^{-1} (45 cm x 5 cm)	6.26	0.59	0.55	0.33	0.67	1.82
S.Em±	0.05	0.01	0.01	0.004	0.007	0.005
C.D.at 5%	0.15	0.02	0.02	0.01	0.02	0.01
Interaction (F x D)						
S.Em±	0.09	0.01	0.01	0.02	0.01	0.01
C.D.at 5%	NS	NS	NS	NS	NS	NS
General mean	6.37	0.61	0.57	0.34	0.69	1.84

Table 2: NPK uptake kg ha^{-1} by soybean as influenced by different treatments

Treatments	Nitrogen uptake			Phosphorus uptake			Potassium uptake		
	Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
Fertilizer level ($N:P_2O_5:K_2O$ Kg ha^{-1}) (F)									
F_1 - 75 % RDF (37.5 : 56.25 : 33.75)	148.90	20.98	169.97	13.12	11.41	24.53	15.97	64.61	80.59
F_2 - 100 % RDF (50 : 75 : 45)	166.50	25.63	192.27	14.79	14.22	29.01	17.91	77.37	95.29
F_3 - 125 % RDF (62.5 : 93.75 : 56.25)	177.20	28.68	205.97	16.16	16.50	32.66	19.47	85.98	105.46
S.Em±	1.29	0.41	1.70	0.26	0.17	0.43	0.18	0.21	0.39
C.D.at 5%	3.87	1.23	5.1	0.78	0.51	1.29	0.54	0.63	1.17
Plant Density (D)									
D_1 - 1,48,148 plants ha^{-1} (45 cm x 15 cm)	153.0	21.83	174.9	14.02	11.93	25.96	17.35	63.44	80.79
D_2 - 2,22,222 plants ha^{-1} (45 cm x 10 cm)	164.3	25.46	189.8	14.61	14.42	29.04	17.43	78.08	95.52
D_3 - 4,44,444 plants ha^{-1} (45 cm x 5 cm)	174.9	27.92	202.8	15.36	15.61	30.98	18.71	86.14	104.8
S.Em±	1.29	0.41	1.70	0.26	0.17	0.43	0.18	0.21	0.39
C.D.at 5%	3.87	1.23	5.10	0.78	0.51	1.29	0.54	0.63	1.17
Interaction (F x D)									
S.Em±	2.32	0.41	2.73	0.26	0.83	1.09	0.26	0.41	0.68
C.D.at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
General mean	164.2	25.10	189.4	14.69	14.04	28.73	17.78	75.99	93.78

Table 3: Available NPK kg ha^{-1} in soil after harvest of soybean as influenced by different treatments

Treatments	N	P_2O_5	K_2O	pH	EC (dS m^{-1})	OC (%)
Fertilizer level ($N:P_2O_5:K_2O$ Kg ha^{-1}) (F)						
F_1 - 75 % RDF (37.5 : 56.25 : 33.75)	230.94	21.30	274.43	7.75	0.08	0.91
F_2 - 100 % RDF (50 : 75 : 45)	231.11	21.96	275.59	7.75	0.10	0.90
F_3 - 125 % RDF (62.5 : 93.75 : 56.25)	231.28	22.13	276.09	7.74	0.12	0.90
S.Em±	0.43	0.40	0.80	0.05	0.007	0.01
C.D.at 5%	NS	NS	NS	NS	NS	NS
Plant Density (D)						
D_1 - 1,48,148 plants ha^{-1} (45 cm x 15 cm)	231.56	22.44	276.89	7.75	0.08	0.89
D_2 - 2,22,222 plants ha^{-1} (45 cm x 10 cm)	231.44	21.89	275.33	7.75	0.10	0.90
D_3 - 4,44,444 plants ha^{-1} (45 cm x 5 cm)	230.33	21.06	273.89	7.76	0.12	0.91
S.Em±	0.43	0.40	0.80	0.05	0.007	0.01
C.D.at 5%	NS	NS	NS	NS	NS	NS
Interaction (F x D)						
S.Em±	0.75	0.70	1.39	0.06	0.009	0.012
C.D.at 5%	NS	NS	NS	NS	NS	NS
General mean	231.11	21.80	275.37	7.75	0.10	0.90

Table 4: Seed yield, straw yield (q ha^{-1}), protein content and oil content of soybean as influenced by different treatment

Treatments	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Protein content (%)	Oil content (%)
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	39.13	19.39
F_2 - 100 % RDF (50 : 75 : 45)	25.99	42.02	40.25	19.65
F_3 - 125 % RDF (62.5 : 93.75 : 56.25)	27.44	46.19	40.57	19.93
S.Em±	0.49	0.58	0.31	0.11
C.D.at 5%	1.49	1.74	0.93	0.34
Plant Density (D)				
D_1 - 1,48,148 plants ha^{-1} (45 cm x 15 cm)	23.77	34.11	40.25	20.12
D_2 - 2,22,222 plants ha^{-1} (45 cm x 10 cm)	25.64	42.44	40.06	19.60
D_3 - 4,44,444 plants ha^{-1} (45 cm x 5 cm)	27.94	47.33	39.12	19.26
S.Em±	0.49	0.58	0.31	0.11
C.D.at 5%	1.49	1.74	0.93	0.34
Interaction (F x D)				
S.Em±	0.86	1.00	0.43	0.20
C.D.at 5%	NS	NS	NS	NS
General mean	25.78	41.30	39.98	19.66

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