Effect of integrated nutrient management in soybean variety Tarkari Bhatmas-1 at Khumaltar condition

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Abstract
Soybean (*Glycine max* L. Merril) is an important summer legume in terms of area and production in Nepal. A field experiment was conducted on the farm of National Agronomy Research Centre, Khumaltar, Lalitpur to evaluate the effect of different combination of nutrients on yield and yield component of soybean variety Tarkari Bhatamas-1. The experiment was laid out in a Randomized Complete Block Design (RCBD) consisting of eight nutrient treatments. These were 30:60:30 $N:P_2O_5:K_2O$ kg/ha (recommended dose), 30:80:30 $N:P_2O_5:K_2O$ kg/ha, 50:60:30 $N:P_2O_5:K_2O$ kg/ha, 50:80:30 $N:P_2O_5:K_2O$ kg/ha, 30:60:30 $N:P_2O_5:K_2O$ kg/ha + compost 10 ton/ha, 30:60:30 $N:P_2O_5:K_2O$ kg/ha + Rhizobium inoculation, 30:60:30 $N:P_2O_5:K_2O$ kg/ha + Biochar (@ 330 g/plot and Compost 20 t/ha with four replications. Results of the pooled analysis revealed that maximum grain yield (2258 kg/ha) and straw dry matter (2735 kg/ha) was obtained with the application of compost 20 t/ha followed by 30:60:30 $N:P_2O_5:K_2O$ kg/ha + compost 10 t/ha (2007 kg/ha) and straw dry matter (2394 kg/ha). The number of nodule and nodule dry weight was not affected by different nutrient combination. The number of pods significantly differed with nutrient combinations. The three years result suggested that 20-ton compost/ha or integration of recommended dose of chemical fertilizer with 10-ton compost/ha had shown the best treatment combination for the sustainable production of soybean at Khumaltar condition.

Keywords: Grain yield, nutrient management, Tarkari Bhatmas-1

Introduction
Grain legumes are an integral part of the Nepalese farming system for crop diversification, increase cropping intensity and maintain soil fertility. They have an important role in nutritional security; sustainability of cereal-based cropping system and in the national economy. Accordingly, soybean (*Glycine max* L. Merril) is one of the important summer legumes in Nepal. It is widely grown in mid-hills as an intercrop with maize or in paddy bund that occupies about 80% in terms of total area and production. In Terai and inner Terai, soybean cultivation as a sole crop is gaining popularity in recent years because of the high demand for soy meal in the poultry industry and its diversified use of grains in terms of livestock feeds and human food. Soybean is a good source of protein (45% to 50%), oil (20%), and rich in Vitamin B, C, E and minerals. In an underdeveloped country like Nepal where the majority of the population suffer from malnutrition, it is used as a portion of good supplemental food with cereal (Shrestha *et al*., 2011). It provides a large amount of edible vegetable oil as well as soybean cake and meal which are high protein supplements in mixed feed rations for livestock (Ngalamu *et al*., 2012). Azhari (1987) reported that soybean contains 20 to 22% of essential amino acids and 40% protein. The study by Malik *et al.* (2006) revealed that soybean contains 18-22% oil which comprises 85% cholesterol-free unsaturated fatty acids in comparison to conventional vegetable and animal fats. Soybean also has many food and industrial uses. Vegetable soybeans are also used in the preparation of innovative products such as green milk, green tofu and green noodles (Shanmugasundaram and Yan, 1999). Vegetable soybeans are characterized by large pods with bigger sized seeds (200-250 mg or more per seed) besides seed being green, soft and sweet. These are rich in protein, fat, phosphorus, calcium, iron, thiamin, riboflavin, vitamin E and flavones. A wide range of vegetable soybean varieties have been cultivated and there is an increased consumption of vegetable soybean in South-East Asian countries (Shanmugasundaram, 1991). The nutritional value and protein content are important characteristics of vegetable soybean, which is superior to meat, cow milk and eggs. Vegetable soybean provides more protein of higher quality and is considered as an excellent protein source compared to vegetable pigeon

pea and green peas protein. In addition to domestic consumption, vegetable soybean also has export potential (Patil *et al*., 2017). In Nepal, it occupies an area of 25,179 ha with a total production of 31,567 mt and an average productivity of 1254 kg/ha (MOALD, 2018/19). It has diverse adaptability to varied agro-ecological zones with an altitude ranging from 200 to 2000 m above mean sea level (Sharma, 1994). Demand for soybean has increased with an increase in the poultry business and the majority of soybean meal is being imported from India (Tripathi *et al*., 2015).

Integrated nutrient management practices applied for soybean contributes to the sustainable growth of yield and quality, influences soil health and reduces environmental risks. The use of organic manures with an optimum rate of fertilizers under intensive farming system increased the turnover of nutrients in the soil-plant system. The organic manures along with biofertilizers help in reducing the dose of inorganic fertilizer; which in turn reduces the cost of cultivation and help in improving the soil health (Farhad *et al*., 2017). Balanced fertilization can play a major role to enhance the present yield level. Experimental evidence revealed that the crop is highly responsive to different fertilizers and its yield can be increased remarkably through judicious fertilization (BARI, 1988; Mohamed, 1984; Roy and Singh, 1986; Kazi *et al*., 2002). Although soybean can fix atmospheric N in the soil, this element is necessary for better yield. In recent years, a concept of integrated nutrient supply involving the use of organic manures and inorganic fertilizers has been developed to obtain sustained agricultural production (Gaikwad and Puranik, 1996). Although several field studies have been conducted on nutrient management of soybean in various parts of the world, very few information is available under Nepalese soil conditions. In this context, understanding the different sources of nutrients in increasing soybean production is a felt need of the soybean growers in Nepal. Optimizing the nutrient requirements, selecting the superior sources of the nutrients and judicious use of the nutrients in soybean cultivation is a necessity. Therefore, this study was undertaken to determine the best combination of nutrient for sustainable soybean production.

Materials and Methods

An experiment consisting of eight nutrient management treatments was evaluated in soybean during 2016-2018 at Khumaltar. Nutrient treatments were 30:60:30 $N:P_2O_5:K_2O$ kg/ha (recommended dose, RD), 30:80:30 $N:P_2O_5:K_2O$ kg/ha, 50:60:30 $N:P_2O_5:K_2O$ kg/ha, 50:80:30 $N:P_2O_5:K_2O$ kg/ha, 30:60:30 $N:P_2O_5:K_2O$ kg/ha + compost 10 ton/ha, 30:60:30 $N:P_2O_5:K_2O$ kg/ha + Rhizobium inoculation, 30:60:30 $N:P_2O_5:K_2O$ kg/ha + Biochar (@330 g/plot) and Compost 20 t/ha. The experiment was laid out in RCBD with four replications. Early maturing determinate soybean variety Tarkari Bhatmas-1 was used. Seeding was done on 8 June 2016, 25 April 2017 and 3 May 2018 with a row spacing of 50 cm and 5 cm between plant to plant in a row. The plot size was 3 m x 5 m (6 rows of 5 m long). Chemical fertilizers were applied as basal before seeding. Similarly, 50 g of Rhizobium/plot was mixed with soil and Biochar placed in deep furrows and covered by the soil before seeding. Compost i.e., farmyard manure (FYM) prepared in a compost pit. Thinning was done to one plant per hill a month after seeding. Weeding and earthing up were done as required. Ten plants were randomly selected for measuring plant height, number of pods/plant, unfilled pods/plant, number of branches/plant, number of seeds/pod at physiological maturity. Grain yield and straw dry matter were recorded from a net plot area of 10 m^2. Crops were harvested from the first week of Septemper to third week of September in 2016 to 2018. Two hundred seeds (2016) and 500 seeds (2017, 2018) were counted to estimate 100 seed weight. Grain yield and seed weight were adjusted to 12% moisture content. Subsample straw was oven-dried to estimate straw dry matter yield.

Temperatures and rainfall during growing season

The mean maximum temperatures during soybean growing season were 27.9 ^oC, 28.3^oC and 28.0^oC in 2016, 2017 and 2018, respectively. Similarly, mean minimum temperatures were 20.1^oC in 2016, 19.1^oC in 2017 and 19.5^oC in 2018 (data not shown). Total rainfall during growing season was highest in 2018 (929 mm) followed by 825 mm in 2017 and 815 mm in 2016.

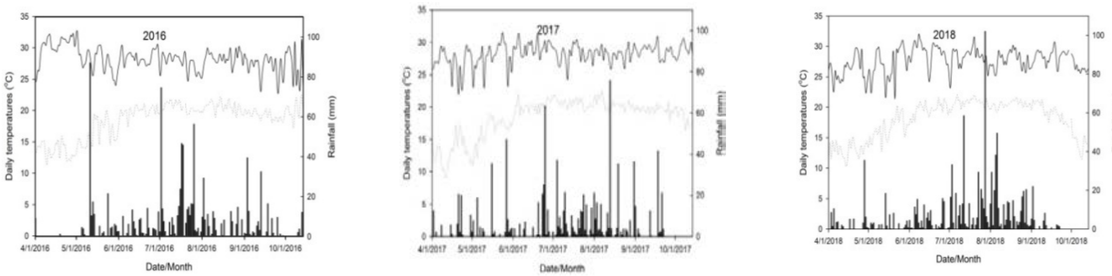

Fig. 1: Daily mean maximum (-●-), minimum (-○-) temperatures and rainfall (solid bar) during soybean growing season in Khumaltar (2016-2018).

Results and Discussions

Plant population

The result showed that the plant stand was significantly affected by treatments in the first year. The plot treated with a recommended dose of NPK with biochar had few numbers of plants stand (Table 1). In the second and third year, there was no significant variation on plant stand, however; few numbers of plant /m^2 were observed on plot treated with the recommended dose of NPK with biochar. But the result of the pooled analysis showed a significant effect on the plant stand.

Table 1. Plant population of Tarkari Bhatmast-1 as affected by nutrient management (2016-2018).

SN	Treatments	Final stand (per m^2)			
		2016	2017	2018	Mean
	Nutrient Management (NM)				
1	30:60:30 $N:P_2O_5:K_2O$ kg/ha (Recommended dose)	21	19	18	19
2	30:80:30 $N:P_2O_5:K_2O$ kg/ha	21	17	18	18
3	50:60:30 $N:P_2O_5:K_2O$ kg/ha	20	19	17	19
4	50:80:30 $N:P_2O_5:K_2O$ kg/ha	21	18	17	18
5	30:60:30 $N:P_2O_5:K_2O$ kg/ha + compost 10 t/ha	21	15	16	17
6	30:60:30 $N:P_2O_5:K_2O$ kg/ha + Rhizobium inoculation	21	18	16	18
7	30:60:30 $N:P_2O_5:K_2O$ kg/ha + Biochar (@ 330 g/plot)	16	15	15	15
8	Compost 20 t/ha	20	17	16	18
	Mean	20	17	17	18
	P value-NM	0.004	0.06	0.316	<.001
	LSD (<0.05)	3	ns	ns	2
	Year (Y) P value				<.001
	LSD (<0.05)				1
	NMxY				0.628
	CV (%)	9	12	11	12

Yield components

The result of the experiment showed that there was a significant effect of treatments on the mean number of pods per plant. The highest numbers of pods per plant were recorded in RD + Biochar, followed by compost 20 t/ha and RD + compost 10 t/ha. The number of 2-seeded pods/plant was significantly higher in RD+ Biochar application in the first year of the experiment (Table 2).

Table 2. Numbers of pods of soybean variety Tarkari Bhatmas-1 (2016) under different nutrient management at Khumaltar

SN	Nutrient Management	2016			2016	2017	2018	Mean
		1-seeded	2-seeded	3-seeded				
	Nutrient Management (NM)							
1	30:60:30 $N:P_2:O_5:K_2O$ kg/ha (Recommended dose)	7	15	5	27	33	36	32
2	30:80:30 $N:P_2:O_5:K_2O$ kg/ha	7	20	5	32	37	32	34
3	50:60:30 $N:P_2:O_5:K_2O$ kg/ha	8	19	5	32	36	37	35
4	50:80:30 $N:P_2:O_5:K_2O$ kg/ha	7	19	6	32	33	34	33
5	30:60:30 $N:P_2:O_5:K_2O$ kg/ha + compost 10 t/ha	9	19	6	35	43	45	41
6	30:60:30 $N:P_2:O_5:K_2O$ kg/ha + Rhizobium inoculation	6	21	5	32	34	37	34
7	30:60:30 $N:P_2:O_5:K_2O$ kg/ha + Biochar (@ 330 g/plot)	8	27	7	42	36	51	43
8	Compost 20 t/ha	9	22	8	38	43	46	42
	Mean	8	20	6	34	37	40	37
	P value-MN	0.128	0.01	0.17	0.013	0.177	0.002	<.001
	LSD (<0.05)	-	5	-	7	-	9	5
	Year (Y) P value							0.003
	LSD (<0.05)							3
	NMxY							0.481
	CV (%)	20	18	24	15	18	15	18

Plant height and nodulation

Plant height and nodule dry weight were significantly different among nutrient management. The highest plant height (54 cm) and nodule dry weight (48.9 mg/plant) were observed in treatment 30:60:30 $N:P_2:O_5:K_2O$ kg/ha + compost 10 t/ha (Table 3). Inoculation of rhizobium did not show a significant effect on nodulation.

Table 3. Plant dry matter and nodule number and dry weight of soybean variety (Tarkari Bhatmas-1) at 54 days after sowing under different nutrient management at Khumaltar, 2016

SN	Nutrient Management	Plant height (cm)	Plant drymatter (g/plant)	Nodule number/plant	Nodule dry weight (mg/plant)
1	30:60:30 $N:P_2:O_5:K_2O$ kg/ha (Recommended dose)	48	13	114	30.6
2	30:80:30 $N:P_2:O_5:K_2O$ kg/ha	47	10	89	23.1
3	50:60:30 $N:P_2:O_5:K_2O$ kg/ha	49	13	106	28.7
4	50:80:30 $N:P_2:O_5:K_2O$ kg/ha	48	11	104	28.9
5	30:60:30 $N:P_2:O_5:K_2O$ kg/ha + compost 10 t/ha	54	13	132	48.9
6	30:60:30 $N:P_2:O_5:K_2O$ kg/ha + Rhizobium inoculation	49	11	143	28.2
7	30:60:30 $N:P_2:O_5:K_2O$ kg/ha + Biochar (@ 330 g/plot)	46	12	98	29.0

SN	Nutrient Management	Plant height (cm)	Plant drymatter (g/plant)	Nodule number/plant	Nodule dry weight (mg/plant)
8	Compost 20 t/ha	53	12	106	41.3
	Mean	49	12	111	32.3
	P value	0.04	0.828	0.614	0.007
	LSD (<0.05)	5	-	-	12.5
	CV (%)	7	23	37	26

Yearly variation in yield and yield attributing traits

There was a significant yearly variation for all parameters. The nutrient management x year interaction was significantly different for maturity only (Table 4). In 2017, plants were slightly taller and had maximum numbers of unfilled pods. Whereas in 2016, plants were matured earlier than in other years and the seed size was slightly large.

Table 4. Yield parameters of soybean variety Tarkari Bhatmas-1 at Khumaltar

Year	Flowering	Maturity	Plant height (cm)	Main branches/plant	Unfill pods/plant	100 seed weight (g)
2016	48	108	45	3	2	22.7
2017	-	127	46	2	9	22.3
2018	66	122	42	3	7	20.8
Mean						
Year (Y)	<.001	<.001	<.001	<.001	<.001	<.001
LSD (<0.05)	0.3	0.4	2	0.4	1	0.4
Nutrient x Y	0.473	0.045	0.365	0.996	0.384	0.473
LSD (<0.05)		1.2	-	-	-	-
CV (%)	0.9	0.7	8	28	33	4

Grain yield and straw biomass production

Grain yield was not significant among various nutrient management treatments in the first year of the experiment (Table 5). Pooled analysis showed a highly significant difference in grain yield and straw dry matter among nutrient management treatments (Table 5). Application of compost @ 20 t/ha alone and in combination with recommended chemical fertilizers (RD) of 30:60:30 N:P_2O_5:K_2O kg/ha produced 24% and 11% higher grain yield as compared to RD only.

Table 5. Grain yield and straw dry matter production of soybean variety Tarkari Bhatmas-1 under different nutrient management at Khumaltar (2016-18)

SN	Nutrient Management	Grain yield (kg/ha)			Straw dry matter (kg/ha)		
		2016	2017	2018	2016	2017	2018
1	30:60:30 N:P_2O_5:K_2O kg/ha (Recommended dose)	2138	1916	1387	1970	2819	2379
2	30:80:30 N:P_2O_5:K_2O kg/ha	2013	1883	1414	2052	2715	2288
3	50:60:30 N:P_2O_5:K_2O kg/ha	1926	1793	1239	1870	2841	2208
4	50:80:30 N:P_2O_5:K_2O kg/ha	1909	1898	1390	1885	2847	2407
5	30:60:30 N:P_2O_5:K_2O kg/ha + compost 10 t/ha	2341	2165	1517	2178	2647	2358
6	30:60:30 N:P_2O_5:K_2O kg/ha + Rhizobium inoculation	2081	1904	1541	1910	2743	2366
7	30:60:30 N:P_2O_5:K_2O kg/ha + Biochar (@ 330 g/plot)	2045	1940	1318	1931	2545	2140
8	Compost 20 t/ha	2389	2611	1776	2544	3021	2641

SN	Nutrient Management	Grain yield (kg/ha)			Straw dry matter (kg/ha)		
		2016	2017	2018	2016	2017	2018
	Mean	2105	2014	1448	2043	2772	2348
	P value	0.290	<.001	0.004	0.002	0.013	0.018
	LSD (<0.05)	-	264	232	308	226	246
	CV (%)	15	9	11	10	6	7

Table 6. Mean grain yield of Tarkari Bhatmast-1 as affected by nutrient management (2016-2018)

SN	Treatments	Grain yield (kg/ha)	Straw dry matter (kg/ha)	HI
	Nutrient Management (NM)			
1	30:60:30 N:P_2:O_5:K_2O kg/ha (Recommended dose)	1814	2377	0.40
2	30:80:30 N:P_2:O_5:K_2O kg/ha	1770	2339	0.40
3	50:60:30 N:P_2:O_5:K_2O kg/ha	1653	2306	0.39
4	50:80:30 N:P_2:O_5:K_2O kg/ha	1732	2379	0.39
5	30:60:30 N:P_2:O_5:K_2O kg/ha + compost 10 t/ha	2007	2394	0.42
6	30:60:30 N:P_2:O_5:K_2O kg/ha + Rhizobium inoculation	1842	2340	0.41
7	30:60:30 N:P_2:O_5:K_2O kg/ha + Biochar (@ 330 g/plot)	1769	2213	0.41
8	Compost 20 t/ha	2258	2735	0.42
	Mean	1856	2385	0.40
	Genotype (G) P value	<.001	<.001	<.001
	LSD (<0.05)	186	155	0.02
	Year (Y) P value	<.001	<.001	<.001
	LSD (<0.05)	114	95	0.01
	NM*Y	0.808	0.193	<.001
	LSD (<0.05)	-	-	0.03
	CV (%)	12	8	5

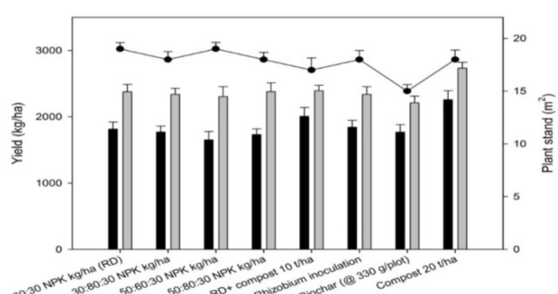

Fig. 2: Final plant stand (-●-), grain yield (black bar) and straw dry matter (gray bar) of soybean variety Tarkari Bhatmas-1 as affected by nutrient management at Khumaltar (2016-18).

Among different nutrient management treatments, few numbers of plant stands were observed from the plot treated with the recommended dose of fertilizer with biochar. This may be due to the presence of some phytotoxic compounds in biochar (Rogovska *et al.*, 2012). However little information is available about the role of biochar in germination. The numbers of pods per plant significantly differed with treatments. The highest number of pods per plant was recorded from the integration of chemical fertilizer with biochar. The result was at par with the integration of recommended dose chemical fertilizer with compost 10 t/ha and compost 20 t/ha alone treated plot. This may be due to the increased uptake of nutrients on biochar treated plot. This result was in line with Mete *et al*. (2015). Similarly, the integration of organic fertilizer with inorganic fertilizer increased the availability of nutrients to the plants. This may be the reason for increasing the number of pods per plant. This result was similar to the findings of Babhulkar *et al.,* (2002). Plant height was significantly influenced by the application of inorganic and organic fertilizer. Integration of organic fertilizers with chemical fertilizers increased the availability of nutrients considerably resulting in a positive effect on growth parameters. These findings are in accordance with the results of Babalad (1999) who had observed increased plant height, the number of trifoliate leaves per plant and the number of branches per plant in soybean due to the application of organic manure and inorganic fertilizers. A similar finding was reported in soybean by another author (Babhulkar *et al*., 2002). Higher nodule weight was observed on plot treated with integration of chemical fertilizer with compost but inoculation of rhizobium had no significant effect on nodule number and nodule weight. This may be due to the buildup of native soil rhizobial population in the Khumaltar Agronomy farm plot. This area was the traditional soybean cultivated area. So, the number of nodules per plant was found in a large number on uninoculated plot also (Maskey and Bhattarai, 2003). The inoculation and chemical fertilization in combination have a significant effect on the total number of nodules/plant (Alam *et al*., 2009).

Grain yield, straw dry matter and harvest index significantly differed with treatments while harvest index was only significant with treatment x year interaction. The seed yield varied from 1653 to 2258 kg/ha in the different treatments. The maximum seed yield (2258 kg/ha) and straw dry matter (2735 kg/ha) were observed with the application of compost 20 t/ha (Tables 5 & 6). The lowest seed yield (1653 kg/ha) was recorded in treatment (50:60:30 N:P_2 O_5:K_2O kg/ha). An increase in grain yield due to FYM may be due to its beneficial effects both on soil and plant by increasing the availability of plant nutrients throughout the growth period resulting in better uptake of nutrients, plant vigor and superior yield attributes (Shivakumar and Ahlawat, 2008). Organic manures along with inorganic fertilizers attribute to higher availability and adsorption of nutrients (Kumar *et al*., 2009). The balanced use of inorganic fertilizer and organic sources of nutrients-maintained soil fertility and physical behaviour resulting in higher soybean yields. Similarly, Chaturvedi and Chandel (2005) found that combined application of 100% recommended dose of NPK+ FYM @ 10 t/ha improved the biological condition which helps to improve the yield of soybean. Ghosh *et al*. (2001) reported that the application of FYM @ 10 t/ha along with the recommended dose of NPK to soybean recorded significantly higher seed yield (2.65 t/ha) compared to NPK alone (1.45 t/ha). This may be due to the continuous supply of nitrogen, phosphorus and potassium to the crop at an early stage from chemical fertilizer and through compost at the later stage of crop growth as slow-release nutrients.

Conclusion

Based on the results, it may be concluded that grain yield and yield attributing characters of soybean can be substantially increased by the integration of organic fertilizer with inorganic fertilizer. More specifically, and application of compost @ 20 t/ha alone or recommended dose of chemical fertilizers of 30:60:30 N:P_2O_5:K_2O kg/ha + compost 10 t/ha produced higher grain yield as compared to other treatments under Khumaltar condition. For the sustainability of soil fertility and soybean crop productivity, judicious use of chemical fertilizers along with organic manures is necessary.

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