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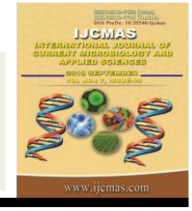

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Nutrient Uptake and Grain Yield Enhancement of Soybean by Integrated Application of Farmyard Manure and NPK

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This study aimed to investigate the impact of integrated application of inorganic fertilizer (NPK) and farmyard manure (FYM) on soybean grain nutrient uptake and yield. We performed field experiments with treatments including 100% NPK, 150% NPK, 100% NPK+FYM and control (without fertilizer), and soil properties and plant parameters assessed. Greater effects on soil electric conductivity (EC), soil organic carbon (SOC), Soil N were recorded with treatments. However, soil P showed significant ($P < 0.05$) interaction with treatments and time. We found that integrated fertilizer application significantly ($P<0.05$) enhanced the nodulation rate, total chlorophyll, grain yield and grain nutrient uptake over control. Overall, integrated use of 100% NPK + FYM may optimize NPK uptake efficiency and reduce N fertilizer losses, which is necessarily required for the sustainable soybean production. This study concluded that FYM with 100% NPK is a best solution for the sustainable soybean production.

Introduction

Oil-seed crop Soybean (*Glycine max* [L.] Merr) is getting globally reputation as largest protein source crop for the animal and human health. Due to the biological nitrogen fixation ability (BNF) through symbiosis of rhizobium bacteria, it mainly used for the rotational crop to secure the soil fertility. Soil organic N and carbon also enhanced by soybean crop residue (Abebe and Deressa, 2017). In India, soybean-grown area is about 10.33 M ha and average productivity 1.20t ha^{-1} and soybean production has influenced in recent years (SOPA, 2016). The soybean yield is restricted due to the lack of developed varieties and insufficient soil and crop management practices. Moreover, high industrial demand, population pressure, climate change and less consistency of breeding crops raises problems in front of the agricultural ministry. To meet the industrial demands, soil nutrients available for the plants needs to use in correct quantity and proportion at the right time. Fertilization has a direct impact on plant-nutrients, and organic fertilizer or soil amendments has been able to improve root nodulation, while inorganic fertilizers reduced (Singh *et al.*, 2007; Ramesh *et al.*, 2010).

Organic fertilizers not only improve the soil physical and biological properties, also improved the efficacy of chemical fertilizers (Alam *et al.*, 2010). Organic fertilizers like FYM increased the soil health by inducing the physical, chemical and biological conditions of soil (Hati *et al.*, 2007). As earlier, to maximize the crop production for the industrial markets, chemical fertilizer strategy applied. However, a strong fertilizer system must be established to improve ecofriendly cultivation of soybean. Past researchers discussed that integrated use of organic and inorganic fertilizers has a positive effect on soil nutrient availability, it optimizes the soil micro- environment and improves crop productivity (Dong *et al.*, 2012; Abebe and Deressa, 2017). Moreover, proportion of organic and inorganic fertilizers as per the specific soil type is required to develop the soil fertility and crop productivity. Present study focused on the assessment of the organic fertilizer (FYM) and inorganic fertilizers (NPK) application impact on the soybean nodulation, photo-light pigment, and grain yield and nutrients uptake.

Materials and Methods

Present study performed during 2015 in Kharif season at experimental site of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India (23°10′N, 79°57′E), under wheat (*Triticum aestivum* L.) as winter and soybean (*Glycine max*) as summer crops. The region has a semi-arid and sub-tropical climate, with a mean annual temperature of 25.7°C and precipitation of 1350 mm. Soil details; medium black soil classified as Vertisol, with pH of 7.6 in soil-water suspension (1:2.5), 0.18 dS m^{-1} electrical conductivity, 0.57% organic carbon, 193.0 kg ha^{-1} available N, 7.60 kg ha^{-1} available P, and 370 kg ha^{-1} available K, 17.47 kg ha^{-1} available S and 0.33 kg ha^{-1} available Zn, and bulk density of 1.3 Mg m^{-3}, and particle size distribution of 56.82% clay, 17.91% silt, and 25.27% sand. All metrological observations given in Table 1. The gross plot size being 17×10.8 m with 1 m spacing in between the plots and 2 m spacing between the replications. An additional strip was also retained as no crop control (fallow strip) by the side of the main experiment. We used four treatments strategy with Soybean variety JS 97-52; included; 100% NPK (43.4, 500, and 33.33 kg ha^{-1} N, P, and K, respectively), 150% NPK (65.1, 750, and 49.99 kg ha^{-1} N, P, and K, respectively), combination of 100% NPK+ FYM (5 t ha^{-1}), and no fertilizer (control). Inorganic fertilizers include urea (460 g kg^{-1} of total N), super phosphate (160 g kg^{-1} of total P), and potassium chloride (600 g kg^{-1} of total K) as the sources of N, P, and K, respectively.

Soil samples were collected from each treatment before showing and after harvesting, five random cores were taken from a depth of 0 to 20 cm using a sampling auger. Subsamples were pooled to make composite samples. Composite samples were air-dried at room temperature, pulverized, sieved through a 2-mm sieve, and chemical properties like pH (1:2.5 water extraction), electrical conductivity (Piper, 1950), organic carbon (Walkley and Black, 1934), available N (Subbiah and Asija, 1956), available P (Olsen, 1954; Millar and Keeney, 1982) and available K (Muhr *et al.*, 1965) were assessed.

For the plant attributes, ten plants were selected from the each plot area, and nodule parameters and total chlorophyll (Arnon, 1949)was measured at different growth stages (25, 45 and 60 days after sowing). All soybean plants were harvested at crop maturity, and grain parameters like number of pods, grain yield, test weight, harvesting index were obtained. After harvesting five tagged plants were collected from, each plot and pods were counted manually and grain test weight was obtained through 1000 grains weight. After threshing of all plants, harvesting index were calculated by using this formula: HI = (Economic yield/ biological yield) × 100 (Snyder and Carlson, 1984). Next to this, grain nutrients NPK were analyzed (Bradstreet, 1965; Bhargava and Raghupati, 1993) and nutrient uptake was calculated by using the following formula: Nutrient uptake (kg^{-1} ha) = Nutrient content (%) × yield (kg ha^{-1}).

For the statistical analysis, data were used as mean ± standard error of four replicates. Significant among treatments was calculated according to Duncan's Multiple Range Test (DMRT). Origin Pro (Origin Lab Corporation, USA) was used for graphs. Box plot indicates the mean by Small Square, the median by central line and Box limits indicate the 25th and 75th percentiles. Whiskers represent the 5th and the 95th percentiles. Black dots showing low and high value of plotted data. Same letter are not significantly different ($P \leq 0.05$) according to DMRT.

Results and Discussion

Soil properties and nutrients

FYM addition as well as composting with various organic supplements have been found to be very efficient for soil management (Hati *et al.,* 2007; Alam *et al.,* 2010). Impact of organic and inorganic fertilization on soil pH have been discussed in past studies (Dong *et al.,* 2012). They confirmed that reduction of pH with inorganic fertilization. In the present study, we observed that integrated use of NPK and FYM on soil pH and EC were not significantly influenced much by different treatments. These outcomes are in agreement with Khan *et al.,* (2017), who found that neither residue nor fertilizer treatments had significant influence on soil pH and EC values. For soil organic carbon (SOC), we observed that there was improvement with integrated use of NPK+FYM, interestingly 100% NPK alone showed less SOC as compared to 150% NPK and 100% NPK+FYM. However, statistical analysis revealed that fertilization treatments led to a significant increase in SOC compared with the control ($P < 0.05$). Organic carbon of soil enhancement through FYM and plant residues might played important role to increase organic matter (Bandyopadhyay *et al.,* 2010; Abebe and Deressa, 2017). Our results showed similarity with the data published by Bandyopadhyay *et al.,* (2010) and Hati *et al.,* (2007) who discussed about effects of manure and inorganic fertilizer applications on SOC. Moreover, soil NPK results also showed less significant pattern with all three fertilization treatments, but maximum NPK resulted with 100% NPK+FYM. We sampled surface soil (0-20 cm) for the NPK and higher organic matter may be inducing the soil nutrients (Table 2). These results also agreement with Khan *et al.,* (2017). Conversely, two-way ANOVA results showed significant ($P = 0.02$) interaction between treatment and time with soil P only, it showed soil total P played important role in soil fertility and soil mineralization and integrated management practices had a positive influence on the soil P. It also suggesting that integrated application can enhance the use of P and it influence the plant nodulation and grain yield (Table 2). These results also supported by Dong *et al.,* 2012, Abebe and Deressa (2017) and Khan *et al.,* (2017). According to our results, SOC and NPK concentration increased considerably in the integrated use of NPK + FYM compared to the control, suggesting that chemical and organic fertilizer are useful to the fortification of soil organic matter, thereby improving soil fertility.

Table.1 Meteorological data during the field experiment (2015)

Meteorological weeks	Temperature (^{0} C)		Relative humidity (%)		Wind velocity (hrs day^{-1})	Sun Shine (hrs day^{-1})	Rainfall (mm)	Rainy days
	Max.	Min.	Max.	Min.				
27	34.5	24.4	85	62	6.9	5.6	296.8	3
28	31.3	23.9	88	77	6.3	4.7	116.0	4
29	32.3	24.1	90	76	6.6	3.1	117.5	3
30	28.2	22.8	95	88	6.9	3.0	119.9	5
31	26.3	22.0	94	87	7.6	0.0	32.4	4
32	27.7	22.7	96	88	6.0	1.2	145.8	5
33	28.2	23.0	89	81	5.9	0.8	101.8	5
34	30.2	22.9	92	77	6.3	4.9	84.4	4
35	31.9	24.2	92	69	3.0	4.8	3.0	0
36	30.8	23.9	93	79	5.4	2.8	52.2	3
37	30.7	23.4	91	79	5.1	2.8	87.4	2
38	30.8	23.1	89	69	3.9	4.6	11.0	1
39	31.9	22.6	88	51	3.1	8.7	0.0	0
40	33.4	21.9	91	44	3.3	7.3	2.3	0
41	32.4	18.5	83	35	2.9	9.0	0.0	0
42	32.5	18.6	79	32	2.4	9.4	0.0	0
43	31.6	15.2	82	35	1.9	8.4	0.0	0

Table.2 Effect of integrated application of fertilizer and FYM on soil physico-chemical properties

Treatments	Sampling time	pH	EC (dSm^{-1})	SOC ($g\ kg^{-1}$)	Available N[#]	Available P[#]	Available K[#]
100% NPK	Showing	7.57±0.00[a]	0.18±0.01[ab]	7.48±0.17[b]	262.50±14.93[b]	32.99±1.69[c]	280.00±9.13[c]
	Harvesting	7.60±0.04[a]	0.19±0.01[ab]	7.57±0.14[b]	266.25±11.61[b]	35.32±2.07b[c]	285.93±10.60[bc]
150% NPK	Showing	7.61±0.06[a]	0.19±0.01[ab]	8.36±0.36[a]	307.50±16.52[ab]	38.63±1.88[ab]	315.00±13.23[abc]
	Harvesting	7.62±0.10[a]	0.20±0.00[a]	8.61±0.38[a]	322.50±16.52[a]	39.63±1.53[ab]	320.00±14.72[ab]
100% NPK+FYM	Showing	7.55±0.06[a]	0.17±0.01[ab]	8.82±0.25[a]	322.50±19.31[a]	40.51±1.09[a]	327.50±20.16[a]
	Harvesting	7.54±0.09[a]	$0.18±0.01_{ab}$	8.90±0.15[a]	326.75±22.56[a]	41.88±1.76[a]	330.00±15.81[a]
Control	Showing	7.51±0.08[a]	0.15±0.02[b]	4.22±0.30[c]	185.00±17.08[c]	9.73±0.72[d]	215.00±6.45[d]
	Harvesting	7.49±0.08[a]	0.16±0.02[ab]	4.21±0.30[c]	183.75±15.46[c]	8.81±1.09[d]	212.50±8.54[d]
SEM		0.07	0.01	0.23	17.34	1.50	12.39
CV%		1.9	15.3	6.2	12.7	9.7	8.7
***P* values[@]**							
Treatments		0.41	0.03*	0.00**	0.00**	0.07	0.79
Time		0.97	0.21	0.60	0.66	0.81	0.89
Treatments × Time		0.99	1.00	0.97	0.97	0.02*	0.99

[#]kg ha^{-1}, Values are mean ± standard error represent in table and means (n=4) followed by same letter within a column are not significantly different (*P* < 0.05) according to Duncan's Multiple Range Test (DMRT). **, *denote significance at 0.01, 0.05 and rest are not significant (*P*> 0.05), respectively. [@]*P* values calculated by two way ANOVA. SEM-standard error of the mean, CV- coefficient of variation

Table.3 Effect of integrated application of fertilizer and FYM on soybean yield parameters

Treatments	Total Pods	Test weight (g)	Grain yield ($kg\ ha^{-1}$)	HI (%)
100%NPK	58.50±2.22[b]	55.45±1.49[a]	900.00±20.41[b]	31.30±0.51[a]
150%NPK	65.25±2.14[ab]	56.78±2.35[a]	1150.00±20.41[a]	36.44±1.85[a]
100%NPK+FYM	67.50±2.78[a]	57.37±2.96[a]	1200.00±20.41[a]	37.33±1.98[a]
Control	46.00±1.83[c]	49.25±0.81[b]	312.50±85.09[c]	14.78±3.24[b]
SEM	2.36	1.77	46.82	1.91
CV (%)	8	6.5	10.5	12.8

Values are mean ± standard error represent in table and means (n=4) followed by same letter within a column are not significantly different (*P* < 0.05) according to Duncan's Multiple Range Test (DMRT). SEM-standard error of the mean, CV- coefficient of variation, HI-harvesting index

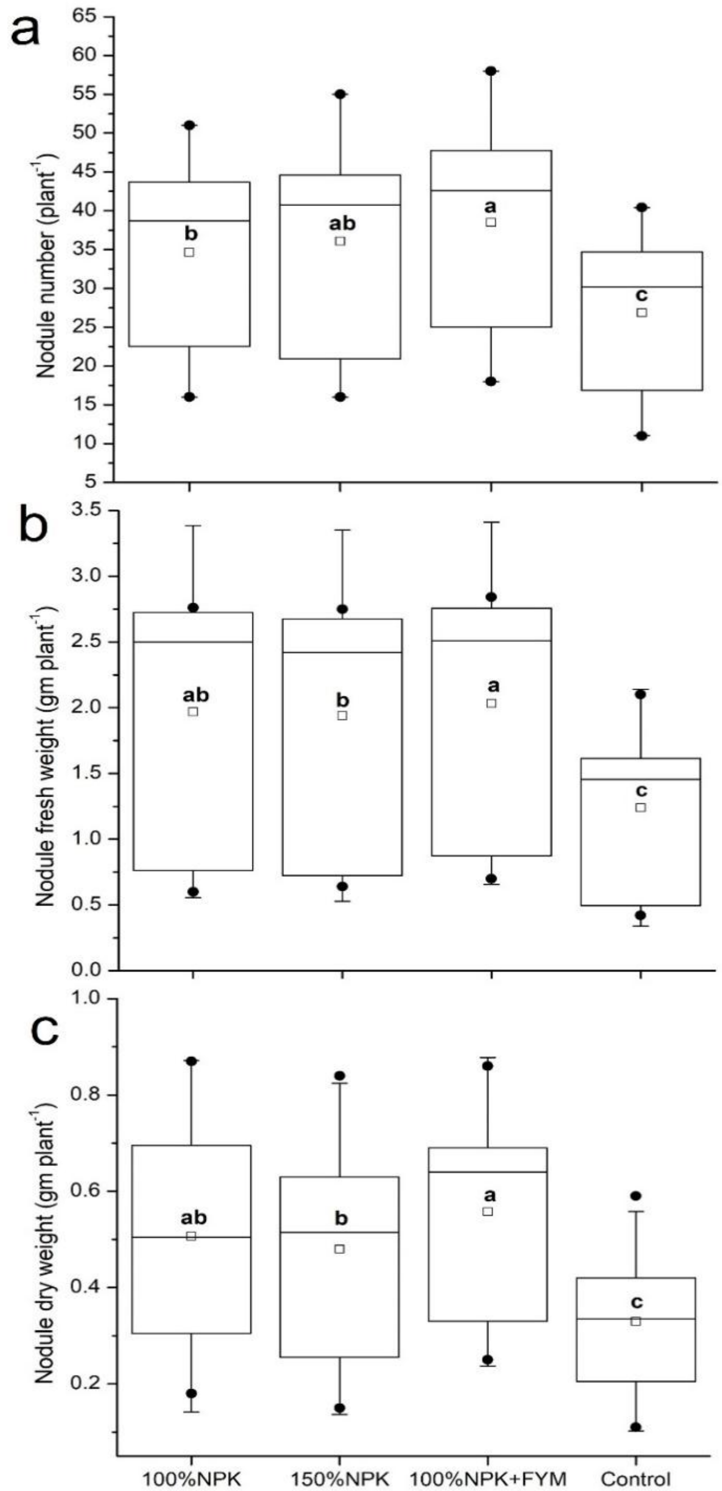

Figure.1 Effect of integrated application of NPK and FYM on nodule parameters of soybean plants; (**a**) number of nodule, (**b**) nodule fresh weight, and (**c**) nodule dry weight. Box graphs represents mean (n=12) of three sampling times (25, 45 and 60 days after sowing)

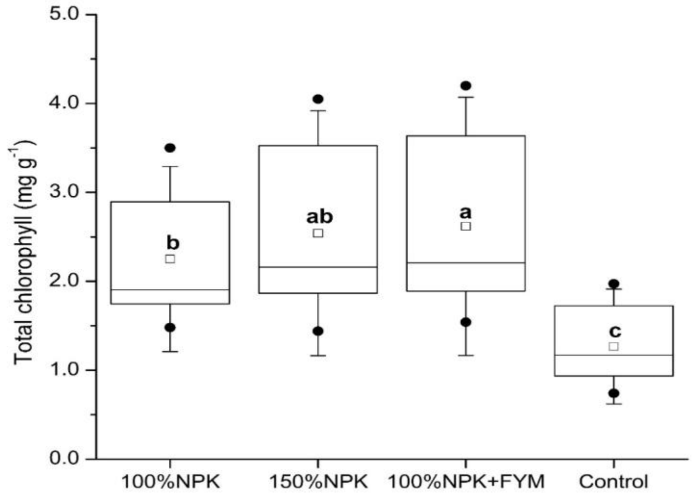

Figure.2 Effect of integrated application of NPK and FYM on total chlorophyll content of soybean plant. Box graphs represents the pooled values mean (n=12) of three sampling times (25, 45 and 60 days after sowing)

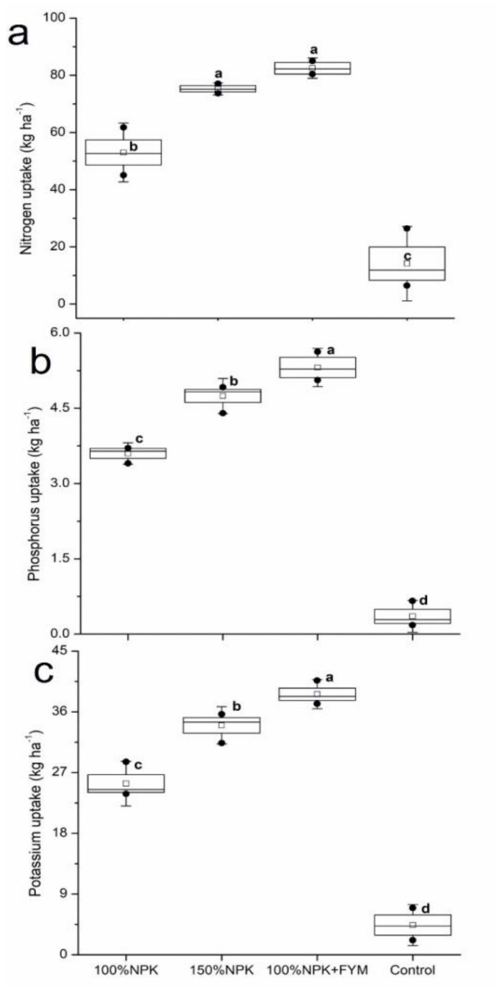

Figure.3 Effect of integrated application of fertilizer and FYM on soybean grain nutrient uptake; (**a**) N uptake, (**b**) P uptake and (**c**) K uptake**.** Box graphs plotted by mean (n=4) after harvesting of grains

Nodule formation and chlorophyll content

Effect of organic fertilizer on nodulation have been reported previously (Bekere *et al.,* 2013; McCoy *et al.,* 2018). In the present study, we found that nodule number, nodule weight (fresh and dry) per plant of the crop were significantly influenced by integrated use of NPK+FYM (Figure 1), it significantly ($P <$ 0.05) improved nodule number (Fig. 1a), nodule fresh weight (Fig. 1b) and nodule dry weight (Fig. 1c) per plant over 100% NPK and control. Higher amount of inorganic fertilizer inhibits the nitrogen fixation but lower amount stimulate increase N_2fixation in early stage of plant (Bekere *et al.,* 2013). Integrated use of NPK+FYM neutralize the toxic effect of inorganic compounds and increase the soil organic matter, and it maintained soil health and biodiversity for the longer time (Dong *et al.,* 2012; Bekere *et al.,* 2013).

The soybean yield usually depends on the N accumulation and chlorophyll content in leaves. N supply increases the leaf area of plants and accordingly that influences the photosynthesis activity. Our results indicated that different treatments showed different leaf chlorophyll contents in soybean (Fig. 2). The total leaf chlorophyll concentration significantly increased with NPK+FYM and 150% NPK, as compared with 100% NPK and control. Integrated fertilizer application resulted in greater amount of chlorophyll content. While lowest content was noted with 100% N alone and control. Similar finding has also been reported by Alam *et al.,* (2010), that lower chlorophyll content would limit the photosynthetic potential, lead to a decrease in biomass, and yield.

Yield parameters and nutrient uptake

Te present study observed that maximum soybean pods, test weight and yield recovered from 100% NPK+FYM, and it significant different with 100%NPK and control. There was similar trend found with 100% NPK+FYM and 150% NPK and a decline noticed in 100% NPK with soybean parameters. The test biomass of soybean grain was higher (P < 0.05) in FYM treated plants and treatment showed significant difference only with control. Similar finding has also been reported by Bandyopadhyay *et al.,* (2010), Hati *et al.,* (2007), Singh *et al.,* (2007). The higher average soybean yield obtained with 100% NPK+FYM (1200.00 ±20.41 kg ha^{-1}), with 150% NPK (1150.00 ±20.41 kg ha^{-1}), with 100% NPK (900.00 ±20.41 kg ha^{-1}) and control (312.50±85.09 kg ha^{-1}) (Table 3). The data clearly correlated that addition of integrated application of fertilizer with FYM was found to be beneficial for maintaining the soil fertility as well as crop productivity (Hati *et al.,* 2007; Bhattacharyya *et al.,* 2008).

For nutrient uptake results indicated that maximum N uptake resulted with 100% NPK+FYM treatment and followed by 150% NPK and 100% NPK over the control (Fig. 3a). These results agreed with Hati *et al.,* (2007) and Bandyopadhyay *et al.,* (2010) reports. Moreover, similar trends also fallowed by P uptake with the 100% NPK+FYM treatment. It was significant ($P <$ 0.05) different as compared with 100% NPK and control (Fig. 3b). Similar kind of finding have been also reported by Sharma and Vikas (2007). The K uptake in soybean grain also showed progressive increase (P<0.05) with NPK+FYM over control. Our results corroborate the previous studies which reported that organic amendments like FYM enhanced the nutrient uptake of soybean grain (Singh *et al.,* 2007; Bandyopadhyay *et al.,* 2010; Ramesh *et al.,* 2010).

Integrated fertilization (NPK+FYM) significantly enriched the soil fertility, which improved the rate of nodulation and photosynthesis. It caused a positively influence on the grain yield and grain nutrient uptake. On average, soybean yields were 3.8 times higher in the integrated fertilized treatments than unfertilized control. FYM application rapidly increased soil N and P, thereafter plant nodulation enhanced and that fixed nitrogen helps to the plant for metabolic activities such as chlorophyll. Higher chlorophyll is a plant health indicator and it increases the pods number and grain test weight. Similar trends also followed by the higher application of NPK (150%). However, application rates 150% NPK were too high, and FYM could have partially replaced the NPK fertilizer inputs. The effectiveness of these measures needs to be tested further in the field with NPK-FYM-Microbes-nutrient strategies.

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