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Response of Sesame (*Sesamum indicum* L.) to Inorganic Nitrogen Application Rates and Organic Fertilizers on Grey Soil in Hochiminh City, Vietnam

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Authors' contributions

This work was carried out in collaboration between both authors. Author NTB designed the study, wrote the protocol and wrote the first draft of the manuscript. Author NTTL reviewed the experimental design and all drafts of the manuscript. Authors NTB and NTTL managed the analyses of the study. Author NTB performed the statistical analysis. Both authors read and approved the final manuscript.

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ABSTRACT

The organic/inorganic fertilizers can contribute substantial N for sesame, but it is not clear that such nitrogen forms are available for plant uptake. A field experiment at agricultural farm of Nong Lam University in HCMc was conducted to study the effect of four inorganic nitrogen application rates (0, 30, 60 and 90 kg N/ha) in combination with two tons of either cow manure or commercial bio-organic fertilizer (BOF) on growth and yield of sesame. The experiment comprised of 2×4×3 factorial in a Split-plot design with three replications. The results show that two organic fertilizers with low nitrogen contents (5–10 g N/kg) and high C/N ratios (28–30) by themselves are not capable of supplying enough nitrogen for sesame requirement. The additional application of inorganic nitrogen at rate of 30 kg N/ha resulted in maximum plant height (106.4 cm), number of capsules/plant (60.13), weight of capsule (1.01 g), number of seeds/capsule (71.0), weight of 1000 seeds (2.63 g), and highest actual yield (0.85 ton/ha). The combination of organic with inorganic N fertilizer, therefore, needs to consider the effective use of nitrogen from each source to maintaining sesame yield, while avoiding undesirable environmental impacts.

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Keywords: Bio-organic fertilizer; cow manure; inorganic nitrogen; sesame; seed yield.

1. INTRODUCTION

Sesame *(Sesamum indicum* L.) is probably one of the oldest cultivated oilseed crops worldwide [1]. According to the FAO, Vietnam had a total sesame harvested area of about 43.000 ha, mainly distributed in the Central Coast, the Mekong River Delta, and the Southeast, with an average seed yield of 0.81 ton/ha [2]. However, due to low yield and strong competition from other oilseed crops, such as soybean, sesame has not been received the appropriate attention and investment.

Sesame has the advantage of being adapted to many soils [3], and it is considered as one of the promising alternative crops in low yield paddy rice-upland crops rotation system [4]. For degraded grey soil in the Southeast of Vietnam having a poor water-nutrient retaining ability, adding soil amendments or fertilizer is needed to improve and maintain crop production. Sesame takes up and use nitrogen readily from inorganic source, while organic source must be converted to ammonium and/or nitrate forms before utilizing them. Case studies on inorganic nitrogen fertilizer for sesame in Vietnam mainly focused on the application rates from 30 to 90 kg N/ha [5,6,7], however, there is little information about the utilization of organic fertilizers which are available on the market. In Vietnam, fertilizers labeling as bio-organic fertilizer (BOF) has attracted the attention of farmers due to containing both necessary nutrients and microbial substances for soil and plant. Organic fertilizers can contribute to total N pool, but it is not clear that such kinds of organic nitrogen are available for plant uptake.

Hence, this present study was firstly designed to study the effects of different application rates of inorganic nitrogen in combination with two kinds of organic fertilizers. The future objectives are to reduce the amount of applied chemical fertilizer by using organic fertilizer more effectively, but maintain sesame yield on grey soil in the Southeast of Vietnam.

2. MATERIALS AND METHODS

A field experiment was conducted during the summer season (March – July) of 2014 at Agricultural Farm, Faculty of Agronomy, Nong Lam University, Vietnam. The mean temperature at experimental site was from 28.7℃ to 30.5℃, lowest in Jun and highest in May. The total monthly rainfall was gradually increased from 0 mm in March to 247.1 mm in July (Fig. 1).

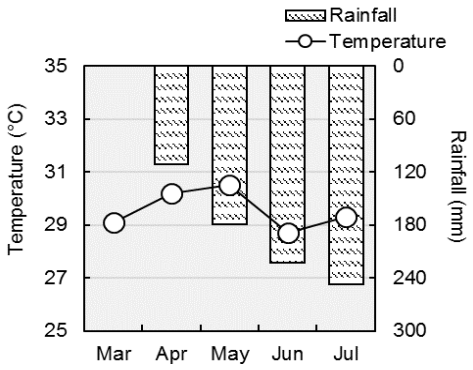

Fig. 1. Montly rainfall and mean temperature at experimental site from March to July, 2014

The experiment was laid out in a Split-plot Design with three replications. Whole plots received the same amount of organic fertilizers (2 tons of either cow manure or BOF), while split plots received four different nitrogen levels (0, 30, 60 and 90 kg N/ha as Urea with 46% N). The net plot area was 10 m^2 (1.60 x 6.25 m) with 5 rows. The distance between rows was 0.25 m, while that of plant-to-plant within rows was 0.20m. Sesame V6 (*Sesame indicum* L.) were sown with 5 seeds/hole, and then thinned to 2 plants/hole at 25 DAS, giving a density of 400.000 plants/ha. The organic fertilizers as per treatment, lime (1.0 ton/ha), phosphorus (60 kg P_2O_5) and potassium (30 kg K_2O) were applied as base application at 14 days before sowing. Half of total inorganic N fertilizer was supplied as per treatment at the date of sowing, the remaining ½ of N was supplied on date of thinning when plant heights were about 20 – 30 cm. Other agronomic practices such as weed control were done throughout the experiment.

Soil samples were collected at 0-30 cm depth before and after base application of above amendments. The soil of the experimental site was sandy clay loam, having very low values of organic carbon and total nitrogen. The results show that soil total organic carbon, available phosphorus, potassium, and cations in depth of 0-30 cm were improved after base application of organic fertilizer, lime, phosphorus, and potassium. Cow manure and BOF were low in total nitrogen (5 – 10 g/kg) but high in C/N ratio

(28 – 30). The other physico-chemical properties of soil and two organic fertilizers following by analysis methods are given in Table 1 and Table 2, respectively.

Plant growth characteristics including plant height, leaf count/plant, stem diameter, and leaf area index of five randomly chosen plants from central rows were measured and determined at weekly intervals, data are shown on the last measuring date at 60 DAS. The height was measured from the soil surface to the tip of the highest leaf. The leaf area index (LAI) was defined by Watson as the total one-sided leaf area per unit ground surface area [8]. Leaf area was estimated by following equation: S = 0.7 CL, where C and L are length and width of leaves, as described by Silva et al. [9]. The seed yield of all plants from each plot was recorded on the harvesting date at 72 DAS. The above 5 tagged plants were harvested separately and data were used for yield components analysis, including number of capsules/plant, capsules length, number of seed/capsule, weight of capsule, weight of seeds/5 capsules and weight of 1000 seeds.

Means of values were compared with those of others by Fisher's protected least significant difference (LSD) after ANOVA test, using EXCEL ® macro add-ins DAAASTAT [10] and Real Statistic Using Excel packages [11].

Table 1. Physico-chemical properties of manure and bio-organic fertilizer in experiment

Fertilizer properties	Organic fertilizers		Analysis method
	Manure	BOF[++]	
Moisture content (%)	29.5	30.0	Oven drying
pH (H_2O) 1:25	5.8	6 - 7	pH meter
Total organic carbon (g/kg)	140.0	300.0	Walkley-Black
Total N (g/kg)	5.0	10.0	Kenjdahl
C/N ratio	28.0	30.0	
Total P (g/kg)	nd[+]	10.0	Acid digestion
Total K (g/kg)	nd	10.0	Acid digestion
Available P (mg/kg)	2.5	nd	Bray-1
Available K (mg/kg)	5.0	nd	NH_4OAc extraction
Exchangeable cation (cmol/kg)			Trilon B
Ca^{2+}	0.4	nd	
Mg^{2+}	0.13	nd	

[+] *nd=not determined*

[++] *Data of BOF were collected on commercial bio-organic fertilizer bag*

Table 2. Soil physico-chemical properties before and after cow manure/BOF + lime application

Soil properties	Before	After application of		Analysis method
		Manure	BOF	
Texture (g/kg)				Hydrometer
Sand	580.6	-	-	
Silt	208.3	-	-	
Clay	211.1	-	-	
Texture class	**Sandy clay loam**			
Bulk density (g/cm^3)	1.51	1.50	1.48	Intact core
pH (H_2O) 1:2.5	5.80	6.0	6.1	pH meter
pH (KCl) 1:2.5	5.40	5.4	5.6	
Total organic C (g/kg)	6.60	7.40	8.70	Walkley-Black
Total N (g/kg)	0.70	0.70	0.71	Kenjdahl
Available P (mg/kg)	100.0	120.0	380.0	Bray-1
Available K (mg/kg)	120.0	132.0	290.0	NH_4OAc extraction
Exchangeable cations (cmol/kg)				Trilon B
Ca^{2+}	1.80	2.05	3.20	
Mg^{2+}	0.48	0.50	0.80	

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Plant height (cm), leaf count/plant, stem diameter (mm) and leaf area index at 60 DAS are given in Fig. 2A, 2B, 2C, and 2D, respectively. Whithin the whole plots with the same organic fertilizer, inorganic nitrogen application rates from 30 to 90 kg N/ha significantly increased plant height and number of leave compared to rate of 0 kg N/ha. Maximum plant height (106.4 cm), number of leave (41.7) and stem diameter (10.6 mm) were recorded in the treatments receiving 30 kg N/ha, while minimum growth parameters were noted at rate of 0 kg N/ha. Stem diameter significantly decreased when increasing N rates from 60 to 90 kg N/ha compared to rate of 30 kg N/ha (Fig. 2C). Leaf area index was not affected by both organic fertilizer and inorganic application rates (Fig. 2D).

3.2 Yield Components

Whithin the whole plots with same organic fertilizer, treatments receiving inorganic N at 30 kg N/ha resulted in highest values of number of capsules/plant (60.13), capsules length (4.23 cm), number of seeds/capsule (71.04), weight of capsule (1.01 g) and weight of seeds/5 capsules (0.55 g), those were significantly different from rate of 0 kg N/ha (Table 3). Similar to growth parameters, the increase of N application rates from 60 to 90 kg N/ha did not enhance yield components, even reduced number of capsules/ plant in comparison to rate of 30 kg N/ha. Utilization of commercial bio-organic fertilizer in this current study was also as

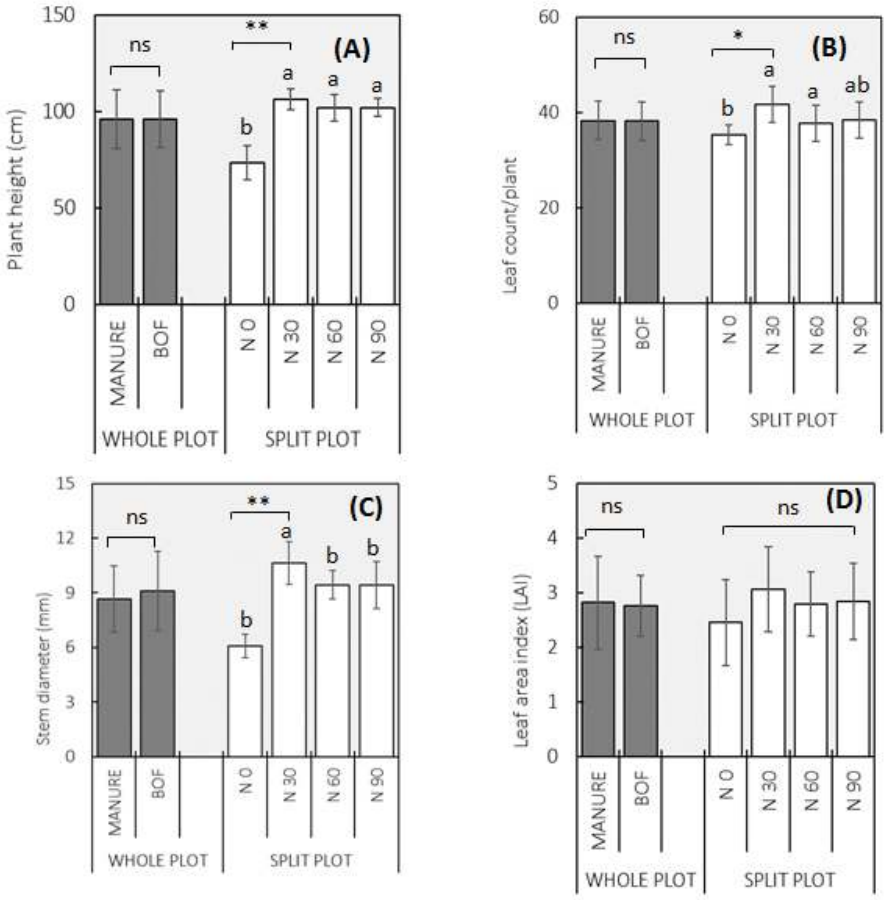

Fig. 2. Plant height (A), leaf count/plant (B), stem diameter (C), and leaf area index (D) as affected by combined organic/inorganic N fertilizer. Vertical bars indicate the standard deviation (n = 12 and n = 6 for organic and inorganic factor, respectively). Columns with the same letters above each item are not significantly different by LSD test

*ns: not significant; significant at *P < 0.05, **P < 0.01*

effective as traditional cow manure, which farmer used to supply as base application on their farms. 1000 seed weight is considered as one of the component factors of the yield. In this test, the 1000 seed weight varied from 2.55 to 2.63 g among inorganic N rates and from 2.58 to 2.60 between two organic fertilizers, that was not affected by organic/inorganic fertilizers.

3.3 Seed Yield

A trend similar to that of yield components was also observed in seed yields. Theoretical seed yields were estimated from yield components, while actual seed yields were obtained from experimental plots. The theoretical seed yields varied from 0.95 ton/ha to 2.25 ton/ha, which were much higher than actual seed yield. The results show that inorganic N application rates from 30 to 90 kg N/ha significantly increased seed yields compared to the control treatment at 0 kg N/ha. Maximum actual seed yield (0.85 ton/ha) was recorded in the treatments receiving 30 kg N/ha, and minimum seed yield (0.50 ton/ha) was recorded in the treatment of 0 kg N/ha. No significant differences in seed yield were observed between application rates from 30 to 90 kg N/ha. Among the split plots with the same rate of inorganic N, the effect of two organic fertilizers on yield components, theoretical yield and actual seed yield were similar (Table 3).

3.4 Correlation Analysis

The results of correlation analysis revealed significant relationships among growth parameters, e.g. plant height vs leaf count/plant (r = 0.98) or stem diameter vs LAI (r = 0.54 – 0.72) (Fig. 3 and Fig. 4). The results in Table 4 show that seed yield strongly correlated with plant height (r = 0.93***), number of

Table 3. Sesame seed yield and yield components as affected by combined organic/inorganic N fertilizer

Factors	Capsules length (cm)	No. of capsules /plant	No. of seeds /capsule	Weight of capsule (g)	Weight of seed /5 capsules (g)	Weight of 1000 seeds (g)	Theoretical seed yield (ton/ha)	Actual seed yield (at 8% H_2O) (ton/ha)
Means of organic fertilizer (A)								
Manure	3.96	49.05	64.74	0.95	0.47	2.58	1.68	0.71
BOF	3.98	49.83	65.64	0.97	0.48	2.60	1.75	0.76
Means of inorganic nitrogen (B)								
0 kg N/ha	3.39 b	36.77 c	50.13 b	0.89 b	0.37 b	2.55	0.95 c	0.50 b
30 kg N/ha	4.23 a	60.13 a	71.04 a	1.01 a	0.55 a	2.63	2.25 a	0.85 a
60 kg N/ha	4.16 a	50.54 b	69.30 a	0.97 a	0.48 ab	2.59	1.82 b	0.81 a
90 kg N/ha	4.10 a	50.33 b	70.28 a	0.97 a	0.50 a	2.59	1.84 b	0.79 a
F test								
A	ns	ns	ns	ns	ns	ns	ns	ns
B	**	**	**	*	**	ns	**	**
A x B	ns	ns	ns	ns	ns	ns	ns	ns

*Mean values for each factor in a column with the same letter are not significantly different by LSD test. ns: not significant; significant at *P < 0.05, ** P < 0.01; n = 12 and n = 6 for organic and inorganic factor, respectively*

Table 4. Correlation coefficient (r) between seed yield and yield components

	ASY	PH	CL	NC	NS	WC	WS	W_{1000}
Actual seed yield (ASY)	1.00	0.93***	0.77***	0.88***	0.86***	0.74***	0.61**	0.64***
Plant height (PH)		1.00	0.84***	0.90***	0.94***	0.65***	0.68***	0.57**
Capsules length (CL)			1.00	0.72***	0.93***	0.66***	0.67***	0.26^{ns}
No. of capsules/plant (NC)				1.00	0.81***	0.58**	0.75***	0.67***
No. of seeds/capsule (NS)					1.00	0.69***	0.76***	0.34^{ns}
Wt. of capsule (WC)						1.00	0.66***	0.30^{ns}
Wt. of seeds/5 capsules (WS)							1.00	0.38^{ns}
Weight of 1000 seeds (W_{1000})								1.00

*Correlations were investigated using Pearson's correlation coefficient test. ns: not significant, significant at *P < 0.05, ** P < 0.01, ***: P < 0.001, n = 24*

capsules/plant (r = 0.88***), number of seed (r = 0.86***), capsule length (r = 0.77***), weight of capsule (r = 0.74***), weight of 1000 seeds (r = 0.64***), and weight of seeds/5 capsules (r = 0.61**). Other Pearson correlation coefficients among yield components are summarized in Table 4.

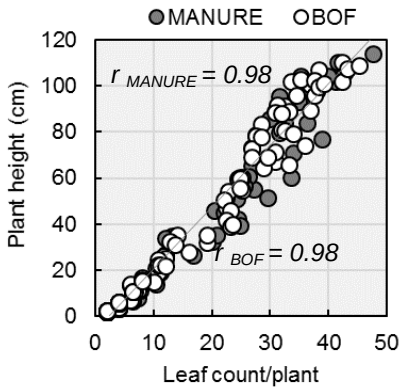

Fig. 3. Relationship between plant height (cm) and leaf count/plant during 11 to 60 DAS, n = 192

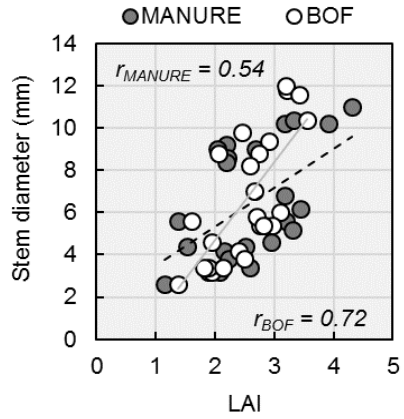

Fig. 4. Relationship between stem diameter (mm) and LAI at 32 and 60 DAS, *n* = 48

Sesame growth and yield increased in response to N fertilizer application over control without N was also reported elsewhere [12,13,14]. Thus, nitrogen stimulates growth, expansion of crop canopy and interception of solar radiation, and the increase in number of capsules/plant might be due to the favorable effect of N on a number of metabolites synthesized and pods setting [15]. Pham suggested that the yield of 1.5 tons/ha should be the target for future cultivar selections on degraded grey soil in the South of Vietnam [16]. The average yield of sesame from this study was lower than above target but higher than average of 0.43 tons/ha [4], probably due to the small experimental area and controlled irrigation condition during the early seedling growth. The positive correlation between grain yield and plant height, yield components was consistent with reports by Delgado and Yermanos [17,18]. Combined application of organic and inorganic N fertilizer significantly improved nitrogen uptake compared to organic fertilizer alone [19]. The lowest values of growth characteristics, yield components and yield on split plots receiving 0 kg N/ha (cow manure or BOF only) suggested that organic fertilizer by themselves could not supply enough nitrogen for sesame requirement. Thus, this N mineralization process of two organic fertilizers could take place slowly due to high C/N ratios of cow manure (C/N=28) and BOF (C/N=30). The effect of N application rates from 60 and 90 kg N/ha was not different from 30 kg N/ha in this study, indicating that either nitrogen requirement of sesame could be met at rate of 30 kg N/ha + 2 tons of organic fertilizers or more inorganic nitrogen could become unavailable for a time due to immobilization into organic forms [19,20]. Our findings are consistent with previous data, of which 2 tons of cow manure plus 30 kg N + 40 kg P_2O_5 + 30 kg K_2O as chemical fertilizer were suitable for sesame varieties cultivated on grey soil in Thu Duc, Hochiminh city [5]. Regarding organic fertilizer, there was no interaction between one of two organic fertilizers and any inorganic N application rates in the current study. However, the amounts of total N, that was amended by 2 tons of cow manure and BOF (10 and 20 kg N/ha, respectively, data were calculated from Table 2), could contribute to the inorganic N pools via N mineralization of organic nitrogen as discussed above, and for a long-term, could increase soil substantial nitrogen sequestration, as reported by Sainju et al. [21].

4. CONCLUSION

These current findings suggested that organic fertilizers with low nitrogen contents (less than 10 g N/kg) and high C/N ratios (28 – 30) by themselves could not supply enough nitrogen for sesame requirement. Additional application of inorganic nitrogen was needed to improve sesame production. An average yield of 0.85 ton/ha was achieved at rate of 30 kg N/ha and 2 tons of cow manure or bio-organic fertilizer. Due to various commercial organic N fertilizers on the Vietnamese market, a combination of organic with inorganic N fertilizer, therefore, needs to consider the effective use of nitrogen from each

source to meet sesame requirements, while avoiding undesirable environmental impacts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

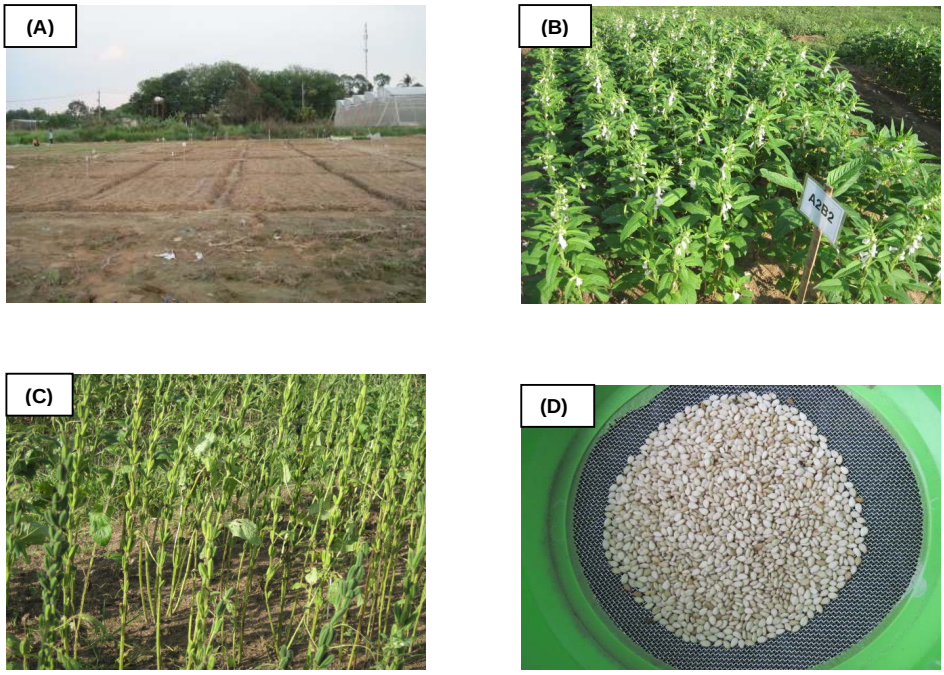

Fig. 5. Overview of experimental site at time of soil preparation (A), sesame at 46 DAS (B), sesame at 60 DAS (C), and sesame seeds after harvesting at rate of 30 kg N/ha + 2 tons of cow manure (D)

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