



Evaluation of Sesame Yield and Yield Component under Different NPSZnB Fertilizer Rates in Western Tigray, Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. Author TS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NG, WH and HA managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Sesame is one of the most popular oil crops in the Western Tigray Ethiopia. Blended fertilizers containing N, P, S, Zn and B have been recommended to ameliorate site specific nutrient deficiencies in different districts of Tigray. Field experiment was conducted during rainfall season of 2018 and 2019 to study the effect of NPSZnB fertilizer on sesame (*Sesamum indicum L.*) in vertisols of Western Tigray at the Humera station, Banat and Kebabo Kafta Humera and Tsegede Wereda's. The treatments consisted of six levels of NPSZnB 0, 50, 100, 150, 200 and 250 kg ha⁻¹ and one blanket recommendation NP was applied. Data were recorded on sesame yield and yield components. The results revealed that addition of graded rate of NPSZnB significantly increased yield and yield attributes over the control. Analysis of variances showed that grain yield, number of capsule per plant, number of seeds per capsule and number of branching per plant was significant differences at (P< 0.001). Grain yield increases from 421 kg ha⁻¹ to 630.1 kg ha⁻¹ as NPSZnB

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increases from 0 (control) to 150 kg ha⁻¹ and 421 kg ha⁻¹ to 626.2 kg ha⁻¹ as NP increases from 0 (control) to 41 N kg and 46 P₂O₅ kg ha⁻¹ respectively. But NPSZnB was not significant with blanket recommendation of NP (41 kg N and 46 kg P₂O₅ ha⁻¹), this indicates that either the blend or blanket NP can be used but not one to replace the other.

Keywords: Blended fertilizer; multi nutrient deficiency; sesame; yield.

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is very important and one of the most ancient oilseed crops in the tropics, where Ethiopia is considered to be the center of cultivation [1]. In Ethiopia, sesame is produced for oilseed and it was ranked as the first in total production from oil crops during 2014/15 cropping season [2]. Sesame production is one of the highest foreign currency earning sectors in Ethiopia. For instance, during the first ten months of 2013, USD 345,967,164 was generated from export of sesame to China, Israel, Turkey, Jordan, and Japan [3]. Therefore, sesame is an important commercial crop produced in Ethiopia as export commodity.

Nutrient mining due to sub optimal fertilizer use coupled with agronomical unblended fertilizer uses have favored the emergence of multi nutrient deficiency in Ethiopian soils [4,5], which in part explain fertilizer factor productivity decline and stagnant crop productivity conditions encountered despite continued use the blanket recommendation. Soil fertility depletion is the major constraint to sustainable agricultural production in Tigray [6]. Poor soil fertility and extreme exhaustion of plant nutrients from the soil are the major factor limiting crop production in both rain-fed and irrigated farms in different agro-ecological zones of Tigray [6].

Most of the Ethiopian soils lack about seven nutrients (N, P, K, S, Cu, Zn and B) [6]. Moreover, [7] reported that grain yield and yield components of wheat (100%) fully responded to applied nitrogen, 72.3% showed response to applied sulfur, 78% showed response to applied phosphorus on eighteen fields studied in central high lands of Ethiopia and strongly indicated sulfur deficiency along with its importance to include in balanced fertilizer formula.

To avoid the situation the Ministry of Agriculture of Ethiopia has been recently introduced a new compound fertilizer NPSZnB containing nitrogen, phosphorous, sulfur, zinc and boron with the ratio of 17% N, 35% P₂O₅, 7% S, 2.2% Zn and 0.1%

B. This fertilizer has been currently substituted DAP and Urea in Ethiopian crop production system as main source of fertilizer [8]; to transform agricultural sector with respect to soil fertility requires application of proper amounts of blended fertilizers for different agro ecologies site specific nutrient deficiencies.

Blended fertilizer containing N, P, S, B, Fe and Zn in blend has been recommended to solve site specific nutrient deficiencies and thereby increase crop production and productivity [9]. The major recently recommended different blended fertilizer for Tigray Region specifically to the study area is NPSZnB [9].

Although the type of required blended fertilizers are identified for the region and specifically to study area, optimum rate of the recommended blended fertilizer type for sesame was not yet determined. Therefore, the objective of this study was to investigate the effects of blended NPSZnB fertilizer rate on yield and yield components sesame in the Kafta humera and Tsegedie district of Western Tigray Ethiopia.

2. MATERIALS AND METHODS

2.1 Description of Experimental Sites

The field experiment was conducted under rain fed conditions in three sites namely on station Banat and Kebabo, Kafta Humera and Tsegedie Wereda's, Western Tigray Ethiopia. Kafta Humera located at 13°10' N to 14°29' N, 36°31' E to 37°34'30" E with an average altitude of 609 masl. Agro ecologies of the district is Wena Dega and Kola. The mean annual rain fall varies from 500-700 mm and with maximum and minimum temperatures of 45°C and 25°C, respectively [10]. Tsegedie Wereda located at 13°4'25" to 14°6'55"N, 36°51'29" to 37°05'25"E with an average altitude of 1850 masl. Agro ecologies of the district are Dega, Wena Dega and Kola. The mean annual rain fall varies from 700-1800 mm and with maximum and minimum temperatures of 42°C and 17.5°C, respectively [10].

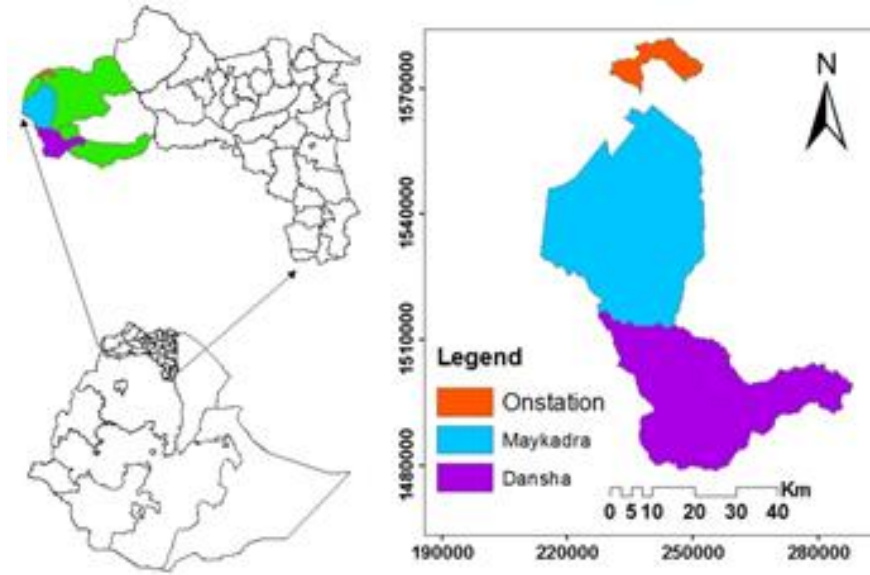


Fig. 1. Map of the study area

2.2 The Experiment

The field was prepared well before sowing by plough twice with tractor and well leveled for seed bed. Seeds of sesame were planted in rows 4*2.8 m long with spacing of 0.4 m between rows. The treatments consisted of 7 rates NPSZnB; 0, 50, 100, 150, 200 and 250 kg ha⁻¹ and blanket recommended N and P fertilizers at the rates of 41kg N ha⁻¹ and 46 kg P₂O₅ ha⁻¹. NPSZnB containing nitrogen, phosphorous, sulfur, zinc and boron with the ratio of 17% N, 35% P₂O₅, 7% S, 2.2% Zn and 0.1% B. The equivalent of N and P was adjusted to the quantity of added nutrient for the blended fertilizer for each treatment.

The amount of nitrogen was applied in split application form 1/3 at sowing and the remaining at week following sowing. All agronomic operations were done. The experiment was arranged in a completely randomized block design (RCBD) with treatment replicated three times in three locations.

Top soil (0-15 cm) was collected from the experimental sites, air dried, sieved through a 2 mm diameter mesh and analyzed for texture, pH, organic matter, total N, available P and CEC following standard procedures at Mekelle Soil Research Center.

Sowing and thinning time in July first week and harvesting time October first week was

conducted each year. Data collection were number of branches, plant height, number of capsules per plant and number of seeds per capsule from five randomly selected plants per plot. Furthermore, grain yield and biological yield were obtained by harvesting an area of 4 m 2.8 from the middle of each plot.

2.3 Statistical Analysis

GenStat® 18th Edition (VSN International, HemelHempstead, UK) was used to perform analyses of variance (ANOVA). Differences between means of significant variables were Duncan's Multiple Range Test (DMRT) at the 5% significance level.

3. RESULTS AND DISCUSSION

3.1 Selected Physicochemical Properties of Soils of the Experimental Sites

The analytical results of the experimental soil indicated that the soil textural class at Humera station, Banat and Kebabo was clay (Table 1).

According to the rating made by Hazelton and Murphy [11] (Table 1) the soil reaction at Humera station was moderately alkaline whereas that of Banat and Kebabo substation were both neutral. According to FAO [8] the pH in the experimental site is within the preferable range for most productive soils (5.5 to 7.5). Thus, the pH of the

experimental soil is optimal for sesame production. Compared to the soil organic matter rating of [12], the organic carbon contents of the soils in all the sites were low (Table 1). Hence, amending the soils with organic fertilizers would be required to enhancing crop yields and soil health.

According to the classification of Tekalign [12] the soil analysis result indicated that total N is a limiting factor for optimum crop growth. Therefore, the soils need amendment with N source. The available soil phosphorous (Olsen P) at all sites was low according to Tekalign [12].

According to the rating of Hazelton and Murphy [11], the soils at the experimental sites high CEC values (Table 1). The high CEC probably facilitates the capacity of the soils in the three sites to retain nutrients against leaching.

3.2 NPSZnB Fertilizer Effect on Agronomic Traits of Sesame

3.2.1 Number of branches

Number of branch per plant for experimental sites the treatments varied across the sites (Table 2). Number of branches per plant for treatments showed significant ($P < 0.05$) difference at all sites (Table 2). The result indicated that 2.6 to 3.83, 2.1 to 2.73 and 2 to 3.77 numbers of branches per plant was recorded at Humera station, Banat and Kebabo respectively. Treatment NPSZnB 200 kg ha⁻¹ was significantly high number of branches per plant ($P < 0.05$), at Humera station, while 200 kg ha⁻¹ treatment 6 and 250 kg ha⁻¹ treatment 7 were higher number of branches at the Banat and Kebabo site over the control but it was at par with preceding rates (Table 2).

The highest number of branches with the various rates of NPSZnB and NP might be due to the increase in number and size of growing cells, ultimately resulting in increased number of branches. The improvement in number of branches with application might be due to the role of P found in NPSZnB in emerging radicle and seminal roots during seedling establishment in sesame [13]. The significant response of the number of branches to the blended fertilizers especially N may have led to increase in photosynthetic activity thereby resulting in heavily branched plant. This in turn enhanced pod production and thus increased seed yield. This result is also in agreement with that of Shah et al. [14] where they obtained the highest tillers in treatment that received the highest nitrogen than control on wheat. Similarly, Mahammad [15] reported significant increase in number of tillers of bread wheat as application of NPK enhanced and recorded the maximum number of tillers with the application of NPK.

3.2.2 Plant height

The experimental sites the treatments showed significant variation ($P < 0.05$) in plant height at Humera station, Banat and Kebabo sites (Table 2). The data for plant height ranged from 145.7-167.47 cm. The tallest plant height at NPSZnB 150 kg ha⁻¹ was recorded in Humera station followed by NPSZnB 200 kg ha⁻¹ and Banat and Kebabo. At Humera station, 145.7 cm was the dwarf followed by 134.93 and 107.3 was the shortest at experimental sites (Table 2).

The increased plant height in response to increasing rate of NP application was probably due to the vital role of NP fertilizer in promoting the vegetative growth and resulted in significant

Table 1. Initial surface (0-15 cm) physical and chemical property of the experimental field

Soil parameters	Experimental sites		
	Humera	Banat	Kebabo
Sand (%)	18	18	15
Silt (%)	31	26	28
Clay (%)	51	56	57
Textural Class	C	C	C
pH(1:2.5 H ₂ O)	7.4	6.91	6.99
Organic Matter (%)	0.73	0.70	0.68
Total Nitrogen (%)	0.02	0.04	0.02
Available Phosphorous(mg kg ⁻¹)	3.7	4.6	4.5
Cation Exchange Capacity (cmol (+) kg ⁻¹)	40	40	41

C - Clayey

increase in plant height. In agreement with this result, [1] found maximum plant height on wheat. This may not be surprising considering the role of P in root development which in turn plays a very important role in the uptake of moisture and nutrients as well as providing anchorage. Its essentiality is noted as it is a constituent of cell nucleus and functions in cell division as energy provider. Moreover, this result is in line with results of Shuaib et al. [16] who reported that application of N and P fertilizer rates increased plant height of bread wheat. The result is also parallel with Dagne [17] who reported that application of Togo blended fertilizer NPKSBZn with micro nutrient increased plant height of maize by 66.81% over control plot and 6.11% over recommended NP fertilizers.

3.2.3 Length of pod bearing zone

The experimental sites the treatments showed significant variation ($P < 0.05$) in length of pod bearing zone at Humera station, Banat and Kebabo sites (Table 2). The data for length of pod bearing zone ranged from 46-79.03 cm. The length of pod bearing zone at NPSZnB 150 kg ha⁻¹ was recorded in Humera station followed by NPSZnB 250 kg ha⁻¹ Banat and NPSZnB 150 kg ha⁻¹ Kebabo. At Humera station, 62.63 cm was the dwarf followed by 62.47 and 46 was the shortest length of pod bearing zone at experimental sites (Table 2). This result is agreement with Shuaib et al. [16] who said when applying both micro (especially Zn, B) and macro nutrients had positive impact on yield component of wheat.

3.2.4 Number of capsules per plant

Number of capsules per plant for experimental sites the treatments varied across the sites (Table 3). Number of capsules per plant for treatments showed significant ($P < 0.05$) difference at all sites (Table 3). The result indicated that 29.63 to 51.8, 36.53 to 42.97 and 29.97 to 50.47 numbers of capsules per plant was recorded at Humera station, Banat and Kebabo respectively. Treatment NPSZnB 150 kg ha⁻¹ was significantly high number of branches per plant ($P < 0.05$), at Humera station, while 250 kg ha⁻¹ treatment 6 and 150 kg ha⁻¹ treatment 5 were higher number of branches at the Banat and Kebabo site over the control but it was at par with preceding rates (Table 3).

The increase in the number of capsules per plant produced in response to the increased application rates of NP fertilizer may be due to

the roles played by NP in enhancing capsules production by the plant. Likewise, Mengistu [18] reported that nitrogen fertilization have significant effect on effective number of tillers of wheat. Also, Dagne [7] reported that combined application of NP resulted in maximum plant height wheat.

3.2.5 Number of seeds per capsule

Significant differences ($P < 0.05$) were observed among the treatments in number of seeds capsules Kebabo site. Number of seeds per capsules varied between 46.33 and 59.63. Higher number of seeds per capsules ($P < 0.05$), at Kebabo site NPSZnB200 kg ha⁻¹ was higher number of seeds per capsules over the control but it was at par with preceding rates (Table 3). The possible reason for non-response of number of seeds per capsule to applied NPSZnB and NP rates might be due to the low level of difference in nutrient amount among treatments which Trans located from vegetative part to number of seeds per capsule during grain filling stage. This result indicated the number of number of seeds per capsule ranges in Humera station between 66.27 to 71.73 and Banat 62.2b to 67.23 (control) to (200 NPSZnB) kg ha⁻¹.

3.3 NPSZnB Fertilizer Effect on Agronomic Grain Yield of Sesame

Grain yield for testing treatments varied across the sites (Table 3). Grain yield for treatments showed significant ($P < 0.05$) difference at all sites. The result indicated that 501.9 to 773.8, 474.35 to 680.12 and 286.85 to 505.9 grain yield was recorded at Humera station, Banat and Kebabo respectively. 150 kg ha⁻¹ treatment 5 was significantly high grain yield ($P < 0.05$), at Humera station, while 150 kg ha⁻¹ treatment 5 and 200 kg ha⁻¹ treatment 6 were higher grain yield at the Banat and Kebabo site over the control but it was at par with preceding rates (Table 3).

The treatments showed significant variation ($P < 0.05$) in the three at Humera station, Banat and Kebabo sites (Table 3). The data for grain yield ranged from 286.85-773 kg ha⁻¹. The highest grain yield at Humera station was recorded in 150 kg ha⁻¹ NPSZnB followed by Banat, and Kebabo site, 501.9 was the lowest followed by 474.35 and 286.85 kg ha⁻¹ was the lowest at experimental sites (Table 3). Apart from control rates of blended NPSZnB and NP, the preceding rate was not significantly different from the succeeding rates.

The increase in the yield with the application of sulphur might be due to role of sulphur in cell division, cell elongation and setting of cell structure and sulphur might have involved in the improvement of yield related traits of the sesame crop leading to higher seed yield [19]. Zinc is also one of the essential micronutrients which act as a catalytic, regulatory or structural co-factor for a lot of en-zymes and regulatory proteins in plants and animals [20]. Photosynthetic activity and metabolic activity enhanced with the application of boron [21].

The highest grain yield at the highest NPSZnB and NP rates might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to synergetic effect of the three nutrients which enhanced yield components and yield. Nitrogen affects the vegetative as well as yields whereas phosphorus plays a fundamental role in metabolism and energy producing reaction and can withstand the adverse environmental effects, thus resulting in enhanced grain yield. This result is concurrent with Shuaib et al. [16] reported maximum grain yield from plots treated with fertilizer, while minimum grain yield was recorded from control plots on wheat. The result is also in agreement with Bereket et al. [22] who reported that grain

yield of bread wheat increased due to the main effect of nitrogen and phosphorus fertilization and obtained highest grain yields applications of N and P on wheat.

The highest grain yield was obtained from the application of 150 kg ha⁻¹ of NPSZnB at Humera station and Banat and 200 kg ha⁻¹ of NPSZnB at Kebabo. In the locations Kebabo station there were lower on yield of sesame. The difference might be the influence by the environment which could have counted for the lower yield in Banat and Kebabo. Because of the change in the environmental condition that forces the crop to reduce vegetative growth and commence reproductive phase as reported by Kifiriti and Deckers [23].

3.4 Correlation and Regression Analysis

The results of interaction plot in this work showed the performance of treatments across the three locations with reference to yield. Treatment effect was observed in traits evaluated in the study over the control. However, there was no significant effect treatment by location interaction effects on agronomic traits in the study. Thus, part from control rates of blended NPSZnB and NP, the preceding rate was not significantly different from the succeeding rates.

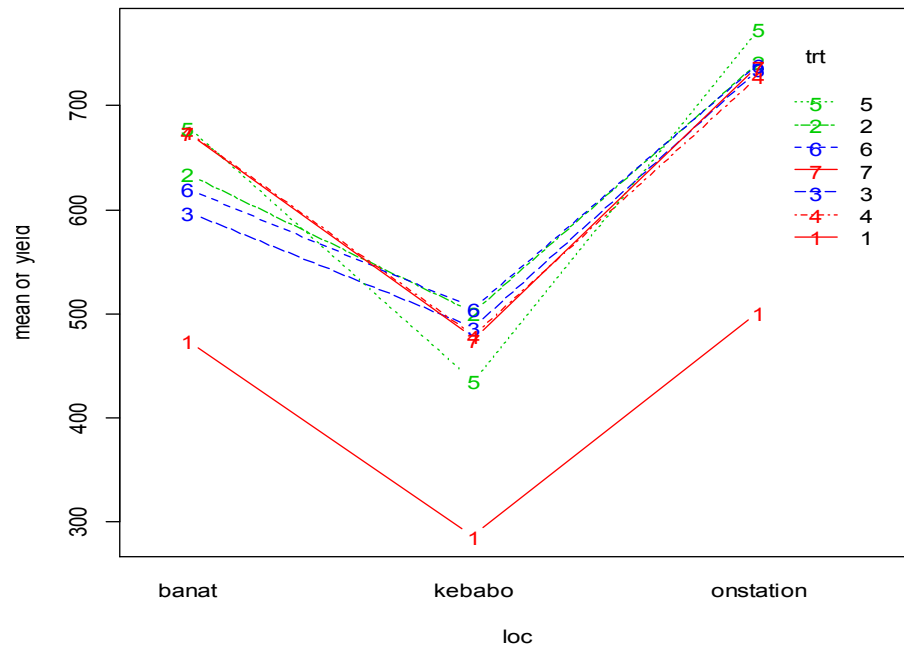


Fig. 2. Interaction plot showing the performance of treatments across the three locations with reference to grain yield of sesame

(trt1= control, trt2 = 41N and 46 P₂O₅ kg ha⁻¹, trt3=50 kg NPSZnB ha⁻¹, trt4=100 kg NPSZnB ha⁻¹, trt5=150 NPSZnB kg ha⁻¹, trt6=200 kg NPSZnB ha⁻¹and trt7=250 kg NPSZnB ha⁻¹)

Table 2. Number of branch, plant height and length of pod bearing zone obtained from across the three sites

Treatment	Number of branch			Plant height			Length of pod bearing zone		
	H. station	Banat	Kebabo	H. station	Banat	Kebabo	H. station	Banat	Kebabo
Control (0)	2.6 ^{defg}	2.1 ^{efg}	2 ^g	145.7 ^{cd}	134.93 ^{def}	107.3 ^h	62.63 ^{efgh}	62.47 ^{efgh}	46i
41 N and 46 p ₂ O ₅	2.9b ^{cdef}	2.3 ^{defg}	3.03 ^{abcd}	165.17 ^a	141.97 ^{cde}	123.07 ^{fg}	79.4 ^a	70.63abcde	52.73 ^{hi}
50	2.93 ^{bcd}	1.87 ^g	2.97 ^{adcde}	167.23 ^a	147.03 ^{cd}	119.83 ^g	73.9 ^{abc}	64.37cdef	56.7 ^{fgh}
100	3.07 ^{abcd}	2.63 ^{cdefg}	3.13 ^{abcd}	161.47a	142.53 ^{cde}	123.97 ^{fg}	75.7 ^{ab}	63.2defgh	53.47 ^{ghi}
150	3.37 ^{abc}	2.07 ^{fg}	3.37 ^{abc}	167.47 ^a	144.77 ^{cd}	124.77 ^{fg}	78.03 ^{ab}	65.5bcdef	56.9 ^{fgh}
200	3.83 ^a	2.27 ^{defg}	3.77 ^{ab}	159.27 ^{ab}	144.33 ^{cd}	131.47 ^{efg}	73.23 ^{abcd}	63.57cdefg	55.77 ^{fghi}
250	3.03 ^{abcd}	2.73 ^{cdefg}	3.43 ^{abc}	158.87 ^{ab}	149.17 ^{bc}	130.43 ^{efg}	72.9 ^{abcde}	70.77abcde	55.6 ^{fghi}
Mean	3.10	2.28	3.10	160.73	143.53	122.97	73.68	65.78	53.88
P-value	<0.04	0.04	<0.001	0.03	0.03	<0.001	0.04	0.02	0.04

Means followed by the same letters are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test (DMRT)

Table 3. Number of capsules per plant, number of seeds per capsule and grain yield obtained from across the three sites

Treatment	Number of capsules per plant			Number of seeds per capsule			Grain yield		
	H. station	Banat	Kebabo	H. station	Banat	Kebabo	H. station	Banat	Kebabo
Control (0)	29.63 ^d	36.53 ^{bcd}	29.97 ^d	66.27 ^{abc}	62.2b ^{cde}	46.33 ^h	501.9 ^{cd}	474.35 ^{cd}	286.85 ^e
41 N and 46 p ₂ O ₅	44.87 ^{abc}	42.6 ^{abcd}	44.33 ^{abc}	69.83 ^{ab}	65.47 ^{abc}	48.9g ^h	742.1 ^{ab}	634.48 ^{abc}	502 ^{cd}
50	42.43 ^{abcd}	35.67 ^{cd}	42.9 ^{abcd}	69.6 ^{ab}	63.23 ^{abcde}	48.03 ^{gh}	735.9 ^{ab}	598.42 ^{bcd}	487.23 ^{cd}
100	47.5 ^{abc}	38.27 ^{abcd}	41.67 ^{abcd}	70 ^{ab}	64.47 ^{abcd}	51.97 ^{fgh}	728.9 ^{ab}	675.69 ^{ab}	479.04 ^{cd}
150	51.8 ^a	34.83 ^{cd}	50.47 ^{ab}	68.8 ^{ab}	59.63 ^{cdef}	55.2 ^{efg}	773.8 ^a	680.12 ^{ab}	436.27 ^d
200	44.6 ^{abc}	39.37 ^{abcd}	47.07 ^{abc}	71.2 ^a	67.53 ^{abc}	59.63 ^{cdef}	740.7 ^{ab}	620.37 ^{abc}	505.9 ^{cd}
250	37.27 ^{bcd}	42.97 ^{abcd}	44.67 ^{abc}	+70.73 ^{ab}	58.6 ^{cdef}	56.17 ^{defg}	738.6 ^{ab}	674.21 ^{ab}	476.42 ^{cd}
Mean	42.585	38.60	43.00	69.49	63.01	52.31	708.84	622.52	453.38
P-value	0.02	0.05	0.04	0.1	0.65	0.04	0.05	0.01	0.04

Means followed by the same letters are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test (DMRT)

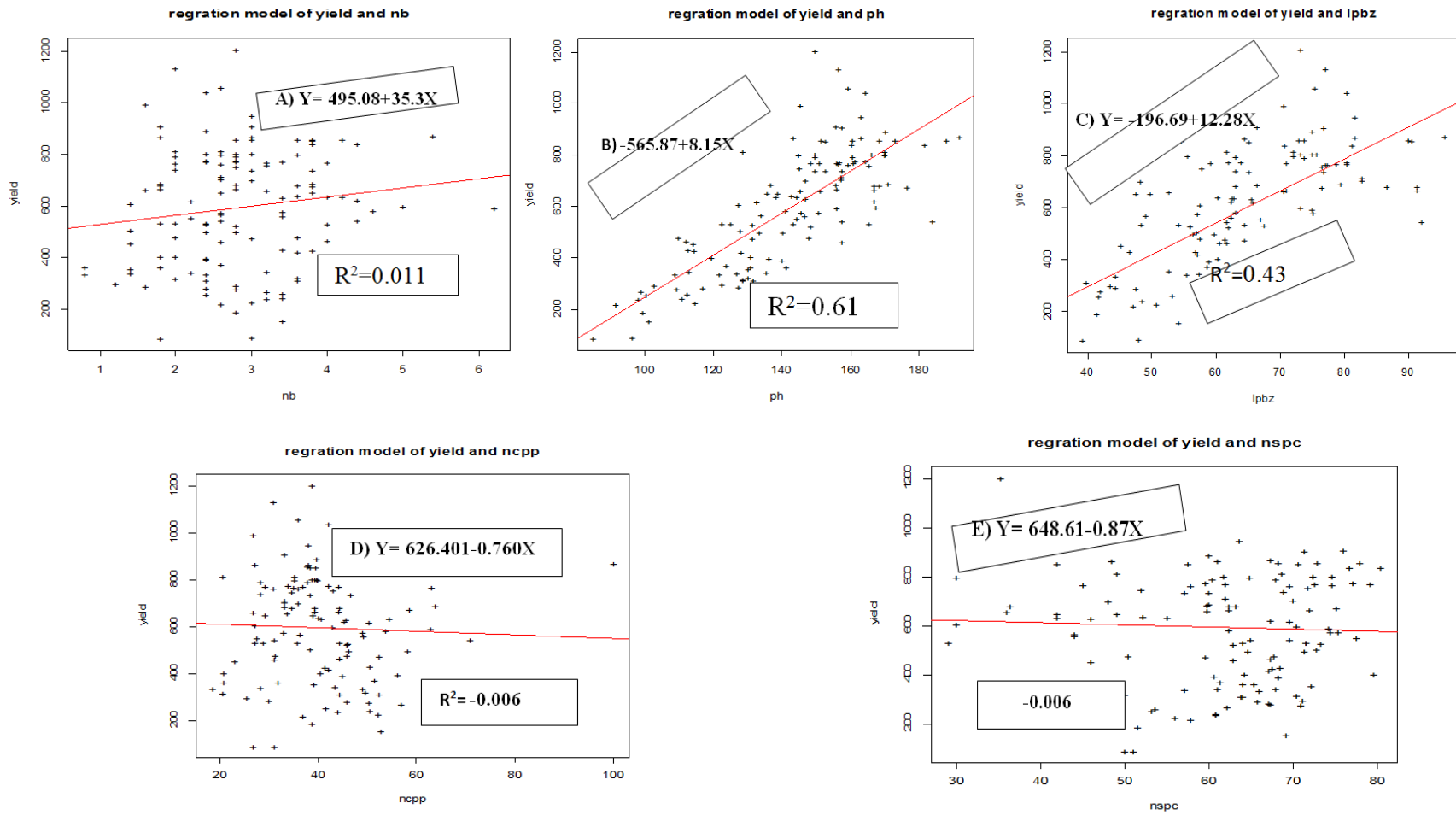


Fig. 3. Linear regression model for grain yield and number of branch per plant (A), Plant height (B), Length of pod bearing zone (C), Number of capsules per plant (D) and Number of seeds per capsule (E) of sesame

Table 4. Simple linear correlation coefficient of grain yield and agronomic parameters of sesame

Grain yield Vs.	Correlation coefficients value	p-value
Number of branch	0.14	0.01
Plant height	0.78	< 0.001
Length of pod bearing zone	0.66	< 0.001
Number of capsule per plant	0.040	< 0.01
Number of seeds per capsule	-0.04	0.63

The best Treatment at the three locations in terms of grain yield was 150 kg ha⁻¹ of NPSZnB, it performed better in all locations (Fig. 2). However, it was statistically at par with most stable treatments across the three locations (Fig. 2).

In order to know their relation, correlation with the Pearson correlation method was applied. grain yield was found to be positively correlated with parameters such as the number of branches per plant, plant height, length of pod bearing zone and number of capsules per plant and negatively correlated with and number of seeds per capsules and not significantly difference (P>0.05) (Table 4). In the present study area the mean grain yield corresponding with plant height was more regressed linearly than the number of branch, length of pod bearing zone and number of capsules per plant (Fig. 3A-E).

4. CONCLUSION

According to this study NPSZnB fertilizer effects on sesame yield and yield components showed that the blended fertilizers would be promising for improving yield of sesame but compared to blanket recommendation NP it has no difference. This indicates that either the blend or blanket NP can be used but not one to replace the other.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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