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Responses of Soybean (*Glycine max* L.) Varieties to NPS Fertilizer Rates at Bako, Western Ethiopia

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Abstract: Soybean (*Glycine max. L*) is among the most important legume crops produced in western Ethiopia. However, declining soil fertility and poor soil fertility management practices decrease yields. A field experiment was conducted in Bako Agricultural Research center during 2018 main cropping season to investigate the effect of NPS rates on yield and yield components of soybean varieties and to identify economically feasible rates of blended NPS rate that increase the productivity. Dhidhessa, Ethio-yugoslavia and Wello of soybean varieties and five rates of NPS (0, 50,100,150 and 200 kg ha^{-1}). The experiment was laid out in arrangement in RCBD with three replications. The highest hundred seed weight (16.9g) was recorded from Ethio-yugoslavia and the lowest (15g) from Wello. Significant effect was exhibited on days to 50% flower, above ground biomass yield and seed yield due to main effects of NPS rate. The highest (55.78) and the lowest (53.78) numbers of days to flowering were recorded due to application of 200 kg NPS ha^{-1} and 0 kg NPS ha^{-1}, respectively. The tallest (81.63cm) and the shortest (65.60 cm) plants were recorded under 200 kg NPS ha^{-1} and 0 kg NPS ha^{-1}, respectively. The highest (8718 kg ha^{-1}) above ground dry mass was obtained at the highest rate of 200 kg NPS ha^{-1} and the lowest (6910 kg ha^{-1}) was due to 0 kg NPS ha^{-1}. The highest (2763 $kgha^{-1}$) seed yield was recorded from the application of 100 $kgha^{-1}$ NPS rate and the lowest (1935$kgha^{-1}$) seed yield was recorded from nil application of NPS fertilizer rate. The best combination with high grain yield and economic benefit is 100$kgha^{-1}$ NPS fertilizer rate with Didhessa Variety. The major measured parameters contributing for grain yield were above ground biomass, number of pod per plant and no of primary branch per plant. This experiment generally confirmed as 100$kgha^{-1}$ NPS for soybean was appropriate. This trial was conducted at strong acid soil, these it is expected as the plants might not have access to use the applied fertilizer and if it was conducted with lime application the responses might be changed. Thus, it can be concluded that combined application of 100 kg ha^{-1} of blended NPS with Dhidhessa variety could be used at similar agro ecology. However, since the study was conducted for one season at one location, it has to be repeated over seasons and locations to make a conclusive recommendation.

Keywords: Blended Fertilizer, Nitrogen, Phosphorus, Sulfur, Yield Component

1. Introduction

Soybean was first introduced to Ethiopia in 1950's because of its nutritional value, multipurpose use and wider adaptability in different cropping systems [1]. It is a crop that can play major role as protein source for resource poor farmers of Ethiopia who cannot afford animal products. Besides, it can also be used as oil crop, animal feed, poultry meal, for soil fertility improvement and more importantly as source of foreign exchange earnings for the country [2]. In Ethiopia, soybean has adapted to diverse ecological niches and provided wider yield range [1].

Soybean was produced on about 38,166.04 ha of land and 81241.833 tons produced in 2015/16 main cropping season with the productivity of 2.1 t ha^{-1}; which is low as compared to world average of 2.6 t ha^{-1} [3]. This low yield may be attributed to a combination of several production constraints among which low soil fertility, periodic moisture stress, diseases and insect-pests, weeds and poor crop management practices play a major role [4]. Soybean is known for its wide adaptability coupled with its higher productivity per unit area compared to other grain legumes [5]. However, it is mostly cultivated in tropical and subtropical areas, where the soils are often deficient in phosphorus (P) and nitrogen (N) due to intensive erosion, weathering, and P fixation by free Fe and Al oxides [6]. Therefore, low P availability is often a major constraint to soybean growth and production [7]. Use of P-efficient soybean varieties with efficient P acquisition ability from both native and added P sources in the soils would be a sustainable and economical approach [6].

Legumes require P for adequate growth and N fixation and their effectiveness in soil improvement can be hindered by P deficiency [8]. Phosphorus deficiency can limit nodulation by legumes and P fertilizer application can overcome the deficiency [9]. N_2 fixation apparatus could not meet N demand [10]. However, yield response of soybean to fertilizer N has been inconsistent at economically acceptable levels [11, 12].

A Bako midland of West Showa Zone of western Ethiopia is one of the midland parts of the country that grows soybean. But it is affected by the low soil fertility problem. To address these nutrient deficiencies, farmers in the study area have been using uniform blanket application of 100 kg DAP ha^{-1} (18 kg N and 46 kg P_2O_5 ha^{-1}) for all legumes including Soybean to increase crop yields and this did not consider soil fertility status and crop requirement.

However, the soil fertility mapping project in Ethiopia reported the deficiency of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils and thus recommend application of customized and balanced fertilizers [13]. This emphasizes the importance of developing an alternative means to meet the demand of nutrient in plants by using of blending NPS that contains S in addition to the commonly used N and P fertilizers. However, there is limited information on responses of soybean varieties to rates of blended NPS fertilizer rates at Bako, Western Ethiopia.

Objective of the study:

1) To assess the effects of blended NPS fertilizer rates on the yield and yield components of soybean varieties.
2) To estimate cost-benefit of blended NPS rate that increases the productivity of the soybean varieties.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was carried out during the main cropping season (June to November) of 2018 at Bako Agricultural Research Center (BARC) which is located in western Ethiopia and located at an altitude of 1650 m above sea level 09^o 6’00” N latitude and 37^o 09’00” E longitude.

2.2. Soil Sampling and Analysis

Pre-planting soil samples were taken randomly in a zigzag method from the experimental plots at the depth of 0-30 cm before planting. A representative soil samples were taken using a cylindrical auger from the whole experimental field and combined to form a composite sample. The collected soil sample was air-dried at room temperature under shade and ground to pass through 2 mm sieve for laboratory analysis. The composite soil samples were analyzed for selected physicochemical properties mainly textural analysis, soil pH, total nitrogen (N), available Sulfur (S), organic carbon (OC), available phosphorus (P), cation exchange capacity (CEC) (c mol kg-1), exchangeable potassium, magnesium and calcium using the appropriate laboratory procedures at Bako Agricultural Research Center Soil Laboratory.

Soil texture was determined by Boycous Hydrometer Method. Organic carbon (OC) was estimated by wet digestion method and organic matter was calculated by multiplying the OC% by a factor of 1.724. Total N was analyzed by Kjeldhal method [14]. The soil pH was measured potentiometrically in 1:2.5 soil-water suspensions with standard glass electrode pH meter [15]. Cation Exchangeable Capacity (CEC) was determined by leaching the soil with neutral 1N ammonium acetate [16]. Available phosphorus was determined by the Olsen’s method using a spectrophotometer [17]. Available sulfur (S) was measured using turbidimetric method [13].

2.3. Treatments and Experimental Design

The treatments were factorial combinations of five blended NPS fertilizer rates (0, 50, 100, 150, 200 kg ha^{-1}) and three varieties of soybean (Dhidhessa, Ethio-Yugoslavia and Wello). Those Varieties are grown by majority of the farmers of the study area and highly adaptable to areas of mid and low altitudes.

Table 1. *Description of the varieties used for the study.*

Adaptation/Attributes	Variety		
	Ethio-Yugoslavia	**Dhidhessa**	**Wello**
Altitude (m. a.s. l)	1900- 1200	1200-1900	750-1850
Rainfall amount (mm)	1000-1200	1000-1200	660-1025
Days to maturity	145-154	137-145	121
Growth habit	Indeterminate	Indeterminate	Bush and half trailing type
Maturity group	Late	Medium	Medium
Yield (t ha^{-1})			
Research field	1.7-3.5	2-3.3	1.92 -3.2
Farmers field	1.6 -3.0	1.4-2.8	1.7-2.2
Year of release	2008	2008	2012
Releasing Institution	BARC	BARC	SARC

Source: MoARD, 2008; MoARD, 2012.

The NPS rate is based on blanket recommendation rate of 100 kg ha $^{-1}$. The experiment was laid out as randomized complete block design (RCBD) and replicated three times. The gross plot size was 3.0 m × 2.8 m = 8.4 m^2. The spacing between blocks and plots were 1.0 m and 0.6 m, respectively. Each plot has 7 rows spaced 40 cm apart. The spacing between plants within row was 10 cm. One outer most row on each side of the plot and two plants (20 cm) on each end of rows were considered as border. One row next to the border rows on any side was used for destructive sampling. The middle 4 rows were used as net rows. The net plot size was 2.6m x1.6m =4.16m^2.

Table 2. *Treatment Combinations of Soybean Varieties and fertilizer rates.*

Treatment and code	NPS rates (kg ha^{-1})	Nutrient rates (kg ha^{-1})		
		N	P_2O_5	S
Ethio-Yugoslavia (T1)	0	0	0	0
Ethio-Yugoslavia (T2)	50	9.5	19	3.5
Ethio-Yugoslavia (T3)	100	19	38	7
Ethio-Yugoslavia (T4)	150	28.5	57	10.5
Ethio-Yugoslavia (T5)	200	38	76	14
Dhidhessa (T6)	0	0	0	0
Dhidhessa (T7)	50	9.5	19	3.5
Dhidhessa (T8)	100	19	38	7
Dhidhessa (T9)	150	28.5	57	10.5
Dhidhessa (T10)	200	38	76	14
Wello (T11)	0	0	0	0
Wello (T12)	50	9.5	19	3.5
Wello (T13)	100	19	38	7
Wello (T14)	150	28.5	57	10.5
Wello (T15)	200	38	76	14

2.4. Experimental Procedure and Crop Management

The land were ploughed by tractor, disked and harrowed. The plots were leveled manually. All the varieties were sown on mid June 2018. The different rates of blended NPS were applied by drilling in prepared rows before planting. The seeds were planted by hand at a specified spacing (40 cm × 10 cm) by placing two seeds per hill and later thinned to one plant per hill after emergence. Furthermore, all necessary cultural and agronomic practices were carried out uniformly for all plots as per the recommendation for the crop at all stages of growth and development. The crop was harvested manually when 90% of the leaves and pods turned yellow and dried under the Sun before threshing. Threshing was done separately for each plot manually.

2.5. Data Collected

2.5.1. Economic Analysis

Economic analysis was performed using partial budget analysis following the procedure described [17] in which prevailing market prices for inputs at planting and for outputs at harvesting were used. All costs and benefits were calculated on ha basis in Birr. The net benefit (NB) was calculated as the difference between the gross benefit and the total cost.

2.5.2. Statistical Data Analysis

All the recorded data were subjected to analysis of variance using Gen Stat statistical software procedure. Least significant difference (LSD) test was used to compare treatment mean differences at the probability level of 0.05.

3. Results and Discussion

3.1. Physico-chemical Properties of the Experimental Site Soil

The result of the experimental soil indicated that the soil textural class at Bako is clay with a particle size distribution of 69.36% clay, 13.98% silt and 14.8% sand (Table 3). The soil reaction is very strongly acid pH 4.84 [18]. Organic carbon content of the soil is 1.3% which was rated as low as per the classification [19]. The available P level in the experimental site was which is 9.6 mg kg^{-1} is low [19, 20]. The result showed that the CEC of the experimental soil to be 23 meq/100 g soils rated as moderate according to rating the CEC values were lower than the mean of 48.2 cmolckg^{-1}presented in that material for soils of Ethiopia [18]. The analysis for available sulfur also indicated that the experimental soil had values of 11.74 mg/kg.

Table 3. *Physico-chemical properties of the experimental site soil before planting.*

Characters	Value	Rating	Reference
A. Soil texture			
Sand (%)	14.8		
Silt (%)	13.98		
Clay (%)	69.36		
Textural Class	Clay		[21]
B. Chemical analysis			
Soil pH	4.84	Very strongly acidic	[21]
Organic carbon (%)	1.3	Low	[22]
Organic Matter	2.24	Low	[22]
Total N (%)	0.08	Very low	[22]
Available P (mg kg^{-1})	9.6	Low	[23]
Available S (mg kg^{-1})	11.74	Low	[13]
CEC [meq/100g soil)	23	Moderate	[21]
Exchangeable Ca (meq/100g) soil	10.6	High	[16]
Exchangeable Mg (meq/100g) soil)	7.7	Very High	[16]

3.2. Yield and Yield Components

3.2.1. Number of Pods Per Plant (NPPP)

The main effect of varieties, NPS and the interaction had non-significance effect on number of pods per plant. However, variety Wello had the highest number of pods per plant (38.3) while variety Ethio-Yugoslavia produced the lowest number of pods per plant (Table 4). With regards to NPS rates, the highest number of pods per plant (40.9) was observed at NPS rate of 100 kg ha^{-1} while the lowest number of pods per plant (32.0) was recorded in unfertilized treatments. Although the number of branches per plant increases as the fertilizer rate increases, the number of pods per plant was not increased. This may be due to abortion of flower at flowering initiation. Similar result was also reported in soybean where the application of 80-120 kg P_2O_5 $ha^{-1}$of soybean increased the number of pods $plant^{-1}$ [24].

3.2.2. Number of Seeds Per Pod (NSPP)

The main effect of varieties, NPS and the interaction had non-significance influence on Number of seeds per pod. However, the highest number of Seeds per pods (2.47) was observed at NPS rate of 150 kg ha^{-1}while the lowest number of Seeds per pods (2.40) was recorded in unfertilized treatments (Table 4). Number of seeds per pod increased with the increased application of NPS rates which might have been due to high N is in NPS rates and changed to vegetative part.

Nitrogen fertilizer had no significant influence on the number of seeds per pod of chickpea [25] Likewise, application of sulfur up to 60 kg ha^{-1} had no significant effect on the number of grains per pod of common bean [26].

3.2.3. Above-ground Dry Biomass Yield (AGDBY)

The main effect of variety and the interaction had no significant effect on AGDBY, however, the main effect of NPS fertilizer rate had significant effect ($P<0.05$) on AGDBY. The highest (8718Kg ha^{-1}) was recorded from the application of highest rate of NPS fertilizer (200 kg NPS ha^{-1}), whereas the lowest (6910 Kg ha^{-1}) biomass yield was obtained from nil NPS rate (Table 4). The result generally showed an increase in biomass production with increase in the rate of blended NPS fertilizer rate. This could be to the fact that the enhanced availability of N significantly increased plant height, number primary branches per plant and to the overall vegetative growth of the plants that contributed to higher aboveground dry biomass yield. This result was in line with total dry matter production increased significantly due to increased nitrogen application from 40 to 120 kg N ha^{-1} on French bean (*Phaseolus vulgaris*) [27].

The same line is reported that application of 120 kg N ha^{-1} significantly increased the dry weight of French bean [28].

The total above-ground dry biomass yield of faba bean significantly increased with increased rate of phosphorus fertilizer application, this is the same with application of sulfur up to 60 kg S ha^{-1} and interaction of nitrogen with sulfur did not result in significant effect on above-ground dry biomass of common bean [24].

3.2.4. Seed Yield

The analysis of variance revealed that the seed yield was affected significantly ($P< 0.05$) by the main effects of NPS fertilizer rate. However, the main effects of Variety and the interaction were non-significant influence on the seed yield.

The highest Seed yield (2763Kg ha^{-1}) was recorded due to the application of (100 kg ha^{-1}) NPS fertilizer rate, whereas the lowest Seed yield (1935Kg ha^{-1}) was obtained from the nil application of fertilizer rate (Table 4). It might also be due to increased levels of S, its availability along with major nutrients and higher uptake of crop and influencing growth and yield components of the crop, which ultimately lead to effective, assimilate partitioning of photosynthesis from source to sink in post-flowering stage and resulted in highest seed yield. Generally, soybean grain yield consistently increased with increase in the rate of applied N to the optimum level of N and the grain yields recorded due to each successive rate of N were different from each other. Seed yield of soybean increased significantly at 40 kg N ha^{-1} compared to the control treatment [29]. However, application of 80 kg N ha^{-1} decreased seed yield, indicating that there is a limit to the maximum level of nitrogen to be supplied to avoid its detrimental effect on the plant. This result might be attributed to the fact that applying NPS fertilizer increases crop growth and yield on soils which are naturally low in NPS and in soils that have been depleted [30]. This result is in line with; revealed as that application of phosphorus influenced the seed yield of French bean (*Phaseolus vulgaris*) significantly up to 60 kg P_2O_5 ha^{-1} [27]. In line with this result, application of S with or without P recorded significantly higher seed yield up to 40 kg S ha^{-1}on chickpea [31] and on black gram [32]. It might also be due to increased levels of S, its availability along with major nutrients and higher uptake of crop and influencing growth and yield components of the crop, which ultimately lead to effective, assimilate partitioning of photo synthates from source to sink in post-flowering stage and resulted in highest seed yield. This reported increased yield response of pulses to seed inoculation of rhizobium [33, 34].

3.2.5. Hundred Seed Weight (HSW)

Hundred seed weights was found to be highly significantly ($P<0.01$) affected by soybean Variety. However, NPS application rates and the interaction effect were non-significant. Variety Wello gave the lowest hundred seed weight (15.06g) as compared to other varieties. There was no significant difference between the other two varieties (Table 4). This indicates that the trait is mainly controlled by genetic factors than the management. In conformity with this result, significant differences among genotypes of chickpea on hundred seed weight [35]. In contrast to this results stated that the number of seeds per pod and weights of hundred seeds were strongly controlled genetically in field bean (*Pisum sativim*) [36].

Table 4. *Mean number of above ground biomass (AGDB), hundred seed weight (HSW) and seed yield (SY) of soybean.*

Treatment	Pod /plant	Seed/pod	AGDB (kg ha^{-1})	HSW (g)	SY (kg ha^{-1})
Varieties					
Dhidhessa	37.1	2.43	8311.0	16.77^{a}	2494
Ethio-Yugoslavia	34.0	2.43	7507.0	16.9^{a}	2399
Wello	38.3	2.43	7130.0	15.06^{b}	2416
LSD (%)	5.71	NS	NS	0.93	NS
NPS rate ($Kgha^{-1}$)					
0	32.0	2.40	6910^{b}	16.22	1935^{b}
50	33.2	2.43	7138^{b}	16.42	2347^{ab}
100	40.9	2.40	8115^{ba}	16.02	2763^{a}
150	36.3	2.47	7366^{b}	16.38	2451^{a}
200	40.0	2.45	8718^{a}	16.16	2685^{a}
LSD (%)	NS	NS	1241.6	NS	461.0

Treatment	Pod /plant	Seed/pod	AGDB (kg ha^{-1})	HSW (g)	SY (kg ha^{-1})
CV (%)	20.9	8.9	16.8	7.7	20.1

Means followed by the same letters are not significantly different as judged by LSD test at 5%, CV= coefficient of variation, AGDB=Above ground dry biomass, HSW= hundred seed weight, SY= seed yield.

3.2.6. Harvest Index

Harvest index of Soybean calculated as the ratio of Seed yield to the above ground dry biomass weight was non-significant due to the main effect of NPS fertilizer rate, variety and Interaction. This may be due to adequate supply of N and S is essential for optimizing partitioning of dry matter between seed and other parts of the soybean plant. Optimum utilization of solar radiation, higher assimilates production and its conversion to starch results in higher biomass, seed yield leading to higher harvest index.

3.2.7. Economic Analysis

The agronomic data upon which the recommendations are based must be relevant to the farmers' own agro-ecological conditions, and the evaluation of those data must be consistent with the farmers' goals and socio-economic circumstances [17].

The net benefit was computed due to Soybean varieties, application of blended NPS fertilizer and interaction of varieties with application of blended NPS fertilizer. The economic analysis revealed that highest net benefit (21,457.2 Birr ha^{-1}) was obtained from combination of variety Dhidhessa with application of 100 kg NPS ha^{-1} while the lowest net benefit (14327.9 Birr ha^{-1}) was obtained from variety Ethio-yugoslavia with nil application fertilizer (Table 5). Generally, the three varieties gave the highest 100 kgha^{-1} except Dhidhessa +50 kgha^{-1} suggesting 100 kgha^{-1} recommendation for soybean is the best recommendation which is replacement with the blanket recommendation.

Table 5. *Result of economic analysis for response of Soybean varieties to rates of blended NPS.*

Treatments	Adjusted yield (kg ha^{-1})	NPS cost (Birr ha^{-1})	NPS application (Birr ha^{-1})	Total Cost (Birr ha^{-1})	Total Revenue (Birr ha^{-1})	Net Benefit (Birr ha^{-1})
Dhidhessa +0	1,902.30	0	0	0	17,120.75	17,120.75
Ethio-Yugoslavia +0	1,591.98	0	0	0	14,327.9	14,327.9
Wello +0	1,729.85	0	0	0	15,568.65	15,568.65
Dhidhessa +50	2,126.91	638	275	913	19,142.19	18,229.19
Ethio-Yugoslavia +50	2,083.70	638	275	913	18,753.38	17,840.38
Wello +50	2,409.54	638	275	913	21,685.9	20,772.9
Dhidhessa +100	2,556.46	1,276	275	1,551	23,008.2	21,457.2
Ethio-Yugoslavia +100	2,418.71	1,276	275	1,551	21,768.39	20,217.39
Wello +100	2,483.99	1,276	275	1,551	22,355.91	20,804.91
Dhidhessa +150	2,162.08	1,914	275	2,189	19,458.76	17,269.76
Ethio-Yugoslavia +150	2,190.95	1,914	275	2,189	19,718.63	17,529.63
Wello +150	2,264.65	1,914	275	2,189	20,381.9	18,192.9
Dhidhessa +200	2,474.82	2,552	275	2,827	22,273.38	19,446.38
Ethio-Yugoslavia +200	2,508.24	2,552	275	2,827	22,574.19	19,747.19
Wello +200	2,267.02	2,552	275	2,827	20,403.25	17,576.25

Where, NPS cost=1276 Birr/100 kg, NPS application cost =275 Birr ha^{-1}, Soybean grain price of all Varieties =9 Birr kg^{-1}

4. Summary and Conclusions

Soybean yield is low compared to other legume crops due to many factors affecting its production which include suitable varieties, poor agronomic practices such as fertility management including appropriate fertilizer rate and time of application, untimely and inappropriate field operations, rainfall variability and diseases and insect pests. Therefore, field experiment was conducted during the 2018 main cropping season at Bako Agricultural Research Center to assess the effect of rates of blended NPS on yield and yield components of soybean varieties and to determine economically appropriate rates of blended NPS fertilizers for soybean production.

The treatment consists of three varieties of soybean (Dhidhessa, Ethio-yugoslavia and Wello) and five rates of NPS (0, 50,100,150 and 200 kg ha^{-1}). The experiment was laid out in factorial arrangement in randomization complete block design (RCBD) with three replications. The result of the analysis of soil samples showed that the soil of the experimental field is clay in texture and had pH of 4.84, 2.24% of organic matter, 0.08% of total N, 1.3% of organic carbon, CEC of 23cmol/kgsoil, available phosphorus of 9.6 mg kg^{-1} and available sulfur of 11.74 mg kg^{-1}. The highest (2763 kg ha^{-1}) seed yield was obtained from the application of 100 kg NPS ha^{-1} and the lowest (1935 kg ha^{-1}) from the control.

Based on the partial budget analysis, the highest net benefit (21,457.2 Birr ha^{-1}) was obtained from combination of variety Dhidhessa with application of 100 kg NPS ha^{-1} whereas lowest net benefit (14327.9 Birr ha^{-1}) was from variety Ethio-yugoslavia with application of nil NPS fertilizer. The major measured parameters contributing for grain yield were above ground biomass, number of pod per plant and no of primary branch per plant. This experiment generally confirmed as 100kgha^{-1} NPS for soybean was appropriate. In most measured traits /parameters the varieties used was not highly variable but Didhessa was the better variety on efficient applied fertilizer utilization. This trial was conducted at strong acid soil, these it is expected as the plants might not have access to use the applied fertilizer and if it was conducted with lime application the responses might be changed. Thus, it can be concluded that application of 100 kg ha^{-1} with variety Dhidhessa was found to be superior and can be used for soybean production in mid-land and similar agro-ecology. However, since the experiment was conducted for one season at one location, it has to be repeated over seasons and locations to make a conclusive recommendation.

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