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Effect of Blended NPS Fertilizer Rates and Plant Population on Yield and Yield Components of Soybean (*Glycine max* L.) in Pawe District, Metekel Zone, North Western Ethiopia.

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ABSTRACT

*Soybean (*Glycine max L. Mirr*) is widely distributed in most parts of the world and has a lot of potentials in Africa and Ethiopia. Among grain legumes, soybean has the highest protein and oil content. So, it is important crop for balance dieted nutrition of human beings and for soil fertility improvement. However, its productivity is very low mainly due to low soil fertility and unbalanced plant population. Based on the national soil database, most of North West Ethiopian soils are deficient in macronutrients (N, P and S) affecting growth, yield and quality of lowland oil and pulse crops in general and soybean in particular. Thus far, emphasis has not been given on assessing influence of inorganic fertilizer and population density on the yield and yield component of soybean. Therefore, a field experiment was conducted to determine the appropriate rate of blended NPS fertilizer by optimum plant population in Pawe District in the 2020. The treatments consisted of five blended NPS fertilizer rates (0, 50,100 150 and 200 kg ha^{-1}) and four inter row spacing (40,50, 60 and 70 cm). The experiment was laid out in 5x4 factorial arrangements in randomized complete block design with three replications. Data on yield components and yield variables were collected and analyzed using SAS version 9.4 software. The analysis of variance revealed that application of blended NPS fertilizer by different inter row spacing significantly ($P<0.05$) influenced number of pods per plant, total dry biomass, grain yield, hundred seed weight and harvest index. The highest number of pods per plant (158.5) and total dry biomass yield (17.43 g/plant) were recorded from application of 200 kg ha^{-1} blended NPS fertilizer by 70cm inter row spacing; while the lowest values were recorded from the control. The highest grain yield (3.123 t ha^{-1}) was recorded from application of 200 kg ha^{-1} blended NPS fertilizer by 40cm inter row spacing. Correlation analysis showed total grain yield was highly significantly and positively correlated to number of pods per plant (r= 0.835), total dry biomass (r= 0.937), hundred seed weight (r= 0.858) and harvest index (r= 0.921). The result of this study verified that yield components and yield were influenced by different blended NPS fertilizer and different inter row spacing. In conclusion, the above findings indicated that the growth and productivity of soybean (Pawe 1 variety) at study area can be improved by the*

application of blended NPS fertilizer and using different plant population. However, further study needs to be conducted at different season, and locations, by considering also higher application rates of blended NPS fertilizer below 40cm inter row spacing.

Keywords: Blended fertilizer, Grain Yield, Plant population, Soybean

INTRODUCTION

Soybean (*Glycine max* L. *Mirr*) is a member of family *Leguminosae* (Ali, 2010). Its herbaceous annual legume, usually erect, bushes and rather leafy which is originated in China (Norman *et al.*, 1996). The crop is widely distributed in most parts of the world and has a lot of potentials in Africa (Nyemba, 1986). Soybean cultivation reached Africa in the late 1800s although little is known of the countries to which it was first introduced. It was first introduced to Ethiopia in 1950`s because of its nutritional value, multipurpose use and wider adaptability in different cropping systems (Amare, 1987).

Soybean has spread to different countries in the world and became an established component of world agriculture. Plant proteins provide nearly 65% of the world protein supply, with 45-50% coming from legumes and cereals to population of developing countries and vegetarians of industrialized nation (Duane and Ted, 2003). Among grain legumes, it has the highest protein and oil content. The Soybean seed on an average contains 40% protein, 20% oil, 35% carbohydrate and about 5% ash, which determine the economic worth of seed in the glob (Thomas and Erostus, 2008).

Since the crop is new to Ethiopia, the identification of areas suitable for production was primary concern in the process of variety development. Soybean has become a crop of growing importance in the country as it has demonstrated an increase in area from 1027 ha in 2003/2004 to 30517.38 ha in 2013/14 cropping season under private peasant holdings with production of 61024.9 tons with average productivity of 2 tons ha^{-1} (CSA, 2004; CSA, 2014) of this 12774.86 ha of land (41.8%) and 24517.6 tons of production (40.1%) are from Benishangul Gumuz Regional State (BGRS) with the average productivity of 1.91 tons ha^{-1} (CSA, 2014). The country average productivity is by far lower than that of the world average productivity which is 2.31 tons ha^{-1} (Masuda and Goldsmith, 2008) and Pawe District soybean productivity which is 2.3 tons ha^{-1} (Derese, 2019) is also low though it is higher than country average productivity. This low productivity is mainly associated with the lack of practicing proper agronomic requirements to the crop of which the major is failure to determine appropriate plant population and maintain plants nutritional requirements. Regions with high potential for soybean in Ethiopia are BGRS and South Nation and Nations Peoples Region (SNNPR). Around Pawe and surrounding of Beles River, there is high potential for scaling up production, especially considering the small scale and large-scale Soybean producers (Ronner and Giller, 2013).

The optimum plant density reported in Kenya was 45 plants m^{-2} (Misiko *et al.*, 2008) while in Ethiopia was 40 plants m^{-2} (Worku and Astatkie, 2011). The above information explicitly indicates that optimum plant population for Soybean could vary depending on geographical location. So, it is relevant to identify the appropriate plant population in each area where Soybean is cultivated. Excess plant population reduces yield due to competition for water, sunlight, nutrient and space, which cause self-thinning, branches and spindly stalks. Similarly, wider spacing rendered low yields due to decreased plant populations/unit area (Kratochivil *et al.*, 2004).

The recommended plant spacing for early and late varieties is 40 x 5 cm and 60 x 5 cm respectively (MoA, 2010). Therefore, maturity length, plant morphology, soil fertility, soil moisture status during growth period, time of sowing, and pest incidences influences plant population per unit area. Phosphorous is a limiting factor to plant growth and productivity on 40% of the world's arable soil (Vance, 2001). The Ethiopian soils, similar to the other agricultural soils of the tropics, are generally low in available P. Several authors have reported independently that 70-75% of Ethiopian agricultural soils are deficient in plant available P (Fisseha *et al.*,2014).

Using blended fertilizer is important to increase productivity of crops. Blended fertilizer contains relatively required elements for crop growth and yield increment. In Ethiopia using this fertilizer was started after previous three years with blanket recommendation. Using phosphorus and nitrogen elements in soybean production is common but sulfur element is not common yet (ATA, 2017).

Phosphorous has several functions in plants as a structural element, being vital for the energy metabolism of cells as an intermediate in metabolic pathways. The absence of P is more detrimental to the productivity of Soybean plants than any other macronutrient, resulting in losses of up to 94% if P is not available to the plants in adequate amounts. This occurs because the P deficiency has a negative impact on the biological fixation of N, which is a process that requires energy (Soares *et al.*, 2014).

Due to constraints like disease, insect pest, weeds, soil and agronomic factors, the average yield of soybean is low. Among various agronomic factors limiting yield, plant density is considered of great importance (Habtamu D., 2018). Optimum plant density with proper geometry of planting is dependent on variety, its growth habit and agro climatic conditions. The optimum plant density to attain highest yield in soybean may vary with the genotype and geographical location.

Soybean seed is planted in rows with a seed drill 2 to 3 cm deep in soil having moisture content or 4 cm in lighter soils. The recommended spacing between rows and plants vary from 40 to 60 cm and 4 to 5 cm respectively. About 65 to 75 kg of seed, 18% nitrogen (N), 46% phosphorous (P_2O_5) and 7% sulfur per hectare (ha^{-1}) is mostly used though fertilizer amount is depends on soil fertility status (ATA, 2017).

Fertilizer use in Ethiopia has increased notably since 1990, but there is no concomitant attainable yield increase, especially in soybean (Derese, 2019). This is mainly due to use of two types of fertilizers (DAP and urea) alone and this may cause unbalanced fertilizers use and use of specific area recommendation to wide areas (Chillot and Hassan, 2010).

Soybean production in different parts of Ethiopia including Pawe area is steadily growing to meet the ever-increasing market demand and yield. At Pawe area, no study was conducted to determine the effect of blended NPS fertilizer rates and plant population on yield and yield components of soybean. Most soybean growers of country traditionally use 60 cm row by 5 cm plant spacing and the so-called blanket recommendation (100kg NPS ha^{-1}), and mostly even below that rate regardless of the agronomic conditions of the location. In Metekel zone condition including Pawe District farmer’s use different inter spacing for soybean production. Though spacing between rows depends on different factors like canopy, soil fertility and cropping system, 60cm, 70cm and 75cm are mostly used. Here the main reason for such different spacing practice is lack of enough information on plant population of soybean around study area (Metekel zone Agriculture Office, 2019).

Farmers in Metekel zone are not using fertilizers in soybean production. Some farmers in Metekel zone even are commonly use less than 100kg ha^{-1} DAP which is main cause not to gain potential yield of the crop (Metekel zone Agriculture Office, 2019). Now a day, Ethio-SIS soil map is identified type of Fertilizer should be used for specific area. In Pawe District case blended NPS fertilizer is identified for most areas though amount of fertilizer for all crops is task should be done after. Due to such reasons now, farmers are using blanket recommendation mostly 100kg ha^{-1} for soybean production. So, the objective of research is to determine the effect of NPS fertilizer rate and plant population on yield and yield components of Soybean.

MATERIALS AND METHODS

Description of the Study Area

Geographically, the study area is located in village 17, Pawe district, Metekel Zone of the Benishangul Gumuz National Regional State, northwest Ethiopia (Figure 1). It is located at about 570 km away from Addis Ababa. The geographical coordinates range from 11° 18´ 40´ to 11º 19´ 29´´ north latitude and from 36º 24´ 26´´ to 36º 25´ 27´´ east longitude. The District covers an area of about 150,000 ha and the altititude varies from 1,000 to 1,200 meters above sea level (m.a.s.l) with much of the area falling in nearly flat to gently undulating topography (PARC, 2012)

The area receives an intensive rainfall with annual mean of 1587 mm. The annual mean maximum temperature is 32.64 ºC and monthly values range between 27.72 and 37.62 ºC while the mean annual minimum temperature is 16.49 ºC and monthly values range between 12.03 and 19.54 ºC. However, the dominant soil types in Pawe District are broadly categorized as Vertisols, which account for 40–45% of the area, Nitisols, which account for 25–30% and other soils of a dark brown color, which account for 25–30% (Viezzoli, 1992).

Treatments and Experimental Design

The experiment have two factors namely five level of blended NPS fertilizer rate (T1 = 0kg ha^{-1}), (T_2= 50kg ha^{-1}), (T_3=100kg ha^{-1}), (T_4=150kg ha^{-1}), (T_5=200kg ha^{-1}) (depend on 100 0kg ha^{-1} blanket recommendation) and four different intra row spacing of soybean (S_1= 40 cm, S_2=50cm, S_3=60cm and S_4=70 cm). Therefore, the treatments were 5x4 = 20 treatments and 60 observations with factorial arrangement in a Randomized Complete Block Design (RCBD) with three replications.

Experimental Procedure

The land was prepared in accordance with the standard practice used by farmers. The experimental plots were cultivated to the depth of 15 to 20 cm. The distance between successive plots and adjacent blocks were 1m and 1.5 m respectively. Seeds were sown by manually placing 5 cm between the seeds with in a row and 40cm, 50cm, 60 and 70cm between rows depend on treatments. Blended NPS fertilizer was used as a source of different nutrients and a full dose which varies depending on treatments were applied at sowing time and other agronomic practices were applied uniformly for each plot.

Data Collected

Numbers of pods per plant, numbers of seeds per pod, hundred seeds weight, grain yield and harvest index (%) were recorded.

RESULTS AND DISCUSSION

Yield and Yield Component Variables

Number of pods per plant

Number of pods per plant was highly significantly *(P<0.01)* influenced by blended NPS fertilizer, interrow spacing variation and their interaction effect. The largest number of pods per plant (158.5) was recorded from application of 200kg ha^{-1} blended NPS fertilizer with 70cm inter row spacing which is statistically similar with application of 200kg ha^{-1} blended NPS fertilizer with 60cm inter row spacing and application of 150kg ha^{-1} blended NPS fertilizer with 70cm and 60cm inter row spacing. The smallest pod number per plant (63.33) was observed from control treatment.

The possible reason for the observed difference on number of pods per plant on soybean could be due to the variations in amount of nitrogen and phosphorus availability. The maximum number of pods per plant observed from the higher N application was related to the increase in the rate N fertilizer resulted in better vegetative growth which in turn enables the crop to produce greater photo assimilate for the production of more number pods (Habtamu Deribe *et al.*, 2018). Here sulfur and boron have also known role on physiology of crops more on photosynthesis (Bewket G., 2020). In addition, plant density has known effect on pod number per plant due to free access on resources relative to more populated one.

The finding of this study is supported by Begum *et al*., (2015), Habtamu Deribe *et al.*, (2018) and Shumid D *et al.* (2020) who reported that soybean varieties were shown variations with different levels of nitrogen and phosphorus fertilizers on number of pods per plant and Habtamu Deribe *et al.*, (2018) and Shumid D *et al.* (2020) also reported the row spacing significantly affects pod number per plant on soybean.

Table 1. Number of pods per plant (NPPP) as influenced by application of blended NPS fertilizer, Inter-row spacing and interaction at Pawe District.

Treatments	NPS (kg ha^{-1})				
	0	50	100	150	200
Inter space(cm)					
40	63.33i	101.13g	118.5ef	147.33abc	150.73ab
50	68.87i	100.73g	130.73de	140.87bcd	144.27bc
60	83.67h	99.13g	142.23bcd	147.57abc	149.1ab
70	95.67gh	116.47f	135.83cd	153.2ab	158.5a
Mean	77.9	104.3	131.8	147.2	150.7
LSD (0.05)	12.83				
CV (%)	6.35				

Means with the same letter are not significantly different at 5% significance level

Hundred seed weight

Statistical analysis of the data revealed that number of pods per plant was highly significantly (*P*<0.*01*) influenced by blended NPS fertilizer, interrow spacing variation and their interaction effect. The maximum hundred seed weight (17.67g) was recorded at application of 200kg ha^{-1} blended NPS fertilizer with 70cm inter row spacing which is statistically similar with application of 200kg ha^{-1} blended NPS fertilizer with 60cm, 50cm and 40cm inter row spacing. The smallest hundred seed weight (13.67g) was observed from control treatment (40cm with no fertilizer) which is in parity with figures recorded from 70cm, 60cm and 50cm with no fertilizer.

Here more hundred seed weight may be due to the fact that nitrogen and phosphorus fertilizer increment increases vegetative growth that results more yield and hundred seed weight. The nutrient use efficiency by crop was enhanced at optimum level of P since grain weight indicates the amount of resource utilized during critical growth periods. In other way, hundred seed weight as a result of increased P application might be attributed to important roles in regenerative growth of the crop, leading to increased seed size, which in turn may improve hundred seed weight (Wondimu W., 2017).

Sulfur and boron also facilitate photosynthesis rate which results more dry matter accumulation and translocation (Bewket G., 2020). This study aligns with Habtamu Deribe *et al.*, (2018) and Shumid D *et al.* (2020) who found that highest hundred seed weight (60.62 g) from application of highest rate of P fertilizer (150 kg ha-1 P), whereas the lowest hundred seed weight (55.42 g) obtained under the control which was statistical in parity with 50 and 100 kg ha-1 P.

Table 2. Hundred seed weight (HSW) as influenced by application of blended NPS fertilizer, Inter-row spacing and interaction at Pawe District.

Treatments	NPS (kg ha^{-1})				
	0	50	100	150	200
Inter space(cm)					
40	13.67h	14.67fg	15.33ef	16.33cd	17abc
50	14gh	14.67fg	15.33ef	16.33cd	17.33ab
60	14gh	14.67fg	15.67de	15.33ef	17.33ab
70	14gh	15ef	16.33cd	16.67bc	17.67a
Mean	13.9	14.7	15.6	16.1	17.3
LSD (0.05)	0.9				
CV (%)	3.52				

Means with the same letter are not significantly different at 5% significance level

Total dry biomass

Total dry biomass yield was highly significantly ($P<0.01$) influenced by blended NPS fertilizer rate, inter row spacing variation and interaction effect. The highest total dry total biomass yield (17.43 g/plant) was obtained from application of 200kg ha^{-1} blended NPS fertilizer with 70cm inter row spacing which is statistically the same with application of 200kg ha^{-1} blended NPS fertilizer with 60cm, 50cm and 40cm inter row spacing. The smallest total dry biomass yield (7.4g/plant) was observed from control treatment (40cm with no fertilizer) which is statistically no difference with figures recorded from 70cm, 60cm and 50cm inter row spacing with no fertilizer.

The possible reasons for the highest total dry biomass observed from the application of highest blended NPS fertilizer may relate with increase in the nutrients in the soil which results free use of nutrients that may lead to high dry matter accumulation. Increasing in total dry biomass with increasing rates of blended NPS fertilizer might be due to the positive effect of nitrogen and phosphorus on dry biomass. Here sulfur and boron also have known benefit by facilitating photosynthesis and producing more photo assimilates (Bewket G., 2020). In addition, plant population has known effect on dry biomass by decreasing competition on resources like nutrient, water and sunlight. Habtamu Deribe *et al.*, (2018) and Shumid D *et al.* (2020) also reported fertilizer application and row spacing increment significantly affects total dry biomass of soybean. Dereje *et al.* (2016) reported significant increases in biomass yield in response to P application.

Table 3. Total dry biomass (TDBM) as influenced by application of blended NPS fertilizer, Inter-row spacing and interaction at Pawe District.

Treatments	NPS (kg ha^{-1})				
	0	50	100	150	200
Inter space(cm)					
40	7.4j	10.07i	12.9f	15.7d	16.93ab
50	7.73j	10.83h	13.53ef	15.8cd	17.27a
60	8.03j	11.07h	13.67e	16.07cd	17ab
70	8j	11.9g	13.43ef	16.4bc	17.43a

Mean	7.7	10.9	13.3	16.7	17.1
LSD (0.05)	0.76				
CV (%)	3.54				

Means with the same letter are not significantly different at 5% significance level

Grain yield

Total grain yield was highly significantly (P<0.01) influenced by the application of blended NPS fertilizer, inter row spacing variation and interaction of these two factors. The highest total grain yield (31.23ku ha^{-1}) was obtained from the application of 200 kg ha^{-1} blended NPS fertilizer with 40cm inter row spacing. This result is statistically not similar with any other treatments. On the other hand, the lowest total grain yield (7.17ku ha^{-1}) was recorded from the control treatment.

Application of 200 kg ha^{-1} blended NPS fertilizer by 40cm inter row spacing increased total grain yield by 77.04% yield gain over control treatment. Increasing rate of blended NPS fertilizer positively influenced total grain yield. The possible reasons for the highest total grain yield observed from the application of blended NPS fertilizer by 40cm inter row spacing was related with increased nutrients in the soil and less plant population that resulted in better vegetative growth which in turn enabled the crops to produce greater photosynthate of the crop. Increasing in total grain yield with increasing rates of blended NPS fertilizer was due to the positive effect of both nitrogen and phosphorus on total grain weight (Begum *et al*., 2015, Habtamu Deribe *et al.*, 2018 and Dereje *et al.*,2016).

Similarly, total grain yield and pod number per plant increased significantly as the rate of sulfur increased, probably due to sulfur's role in the synthesis of sulfur containing amino acids, proteins, energy transformation, activation of enzymes which in turn enhances carbohydrate metabolism and photosynthetic activity of plant with increased chlorophyll synthesis (Bewket G., 2020). Boron application showed significant increase in yield in this study probably due to its role in regulation of carbohydrate metabolism and its transport within the plant besides the synthesis of amino acids and proteins (Debnath and Ghosh, 2011).

Table 4. Grain Yield (GY) as influenced by application of blended NPS fertilizer, Inter-row spacing and interaction at Pawe District.

Treatments	NPS (kg ha^{-1})				
	0	50	100	150	200
Inter space(cm)					
40	8.8m	12k	16.8h	24.5e	31.23a
50	8.47m	12.33k	15.73i	23.17f	29.1b
60	7.6n	11.97k	15.53i	22.27g	27.5c
70	7.17n	10.63l	14.6j	22.17g	25.9d
Mean	8	11.7	15.6	23	28.4
LSD (0.05)	0.78				
CV (%)	2.73				

Means with the same letter are not significantly different at 5% significance level

Harvest Index (%)

The analysis of variance showed highly significant ($P<0.01$) differences in harvest index due to the main effects and interaction. Application of 200kg ha^{-1} blended NPS fertilizer by 40cm inter row spacing results the highest harvest index (65) which is statistically not different with the application of 200kg ha^{-1} blended NPS fertilizer by 50cm inter row spacing (63). On the other hand, the lowest harvest index value 47 was recorded from 50cm inter row spacing with no fertilizer treatment which was statistically similar with the application of 50kg ha^{-1} blended NPS fertilizer by 50cm inter row spacing and 50cm inter row spacing with no fertilizer treatment.

The significant increase in harvest index due fertilizer application may be due more access of nitrogen and phosphorus in the soil that could be attributed to total yield, which could be reflected by improved allocation of photosynthate as a result of more nutrient availability (Walter and Rao, 2015). In addition, in case of inter row spacing narrowly spaced plantation results high harvest index since grain yield is high relative to straw yield.

Table 4. Harvest Index (HI) as influenced by application of blended NPS fertilizer, Inter-row spacing and interaction at Pawe District.

Treatments	NPS (kg ha^{-1})				
	0	50	100	150	200
Inter space(cm)					
40	0.54gh	0.54gh	0.56fg	0.61bc	0.65a
50	0.52hij	0.53hij	0.54hi	0.59de	0.63ab
60	0.49k	0.52ij	0.53hij	0.58def	0.62bc
70	0.47k	0.47k	0.52j	0.58ef	0.6cd
Mean	0.5	0.5	0.5	0.5	0.6
LSD (0.05)	0.02				
CV (%)	2.2				

Means with the same letter are not significantly different at 5% significance level

CONCLUSION

The result indicated that application of blended NPS fertilizer with different inter row spacing was important for the yield component and yield of soybean in the study area. Application of blended NPS fertilizer by different plant population resulted in better performances for some of yield and yield component variables. The results indicated that a combined application of blended NPS fertilizer by different inter row spacing showed significant increase on number of pods per plant, total dry biomass, grain yield, hundred seed weight and harvest index. However, number of seed per pod were not affected by the application of NPS blended fertilizer, inter row spacing and interaction. The highest number of pods per plant (158.5) and total dry biomass yield (17.43 g/plant) were recorded from application of 200 kg ha^{-1} blended NPS fertilizer by 70cm inter row spacing; while the lowest values were recorded from the control. The highest grain yield (3.123 t/ha) was recorded from application of 200 kg ha^{-1} blended NPS fertilizer by 40cm inter row spacing. Total grain yield was highly significantly and positively correlated to number of pods per plant (r= 0.835), total dry biomass (r= 0.937), hundred seed weight (r= 0.858) and harvest index (r= 0.921). Generally, the strong positive correlation was observed among yield and yield component variables of soybean.

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