Research Article

Dose Optimization of NPK Fertilizers for Growing Linseed Crop under Saline Sodic Soil Environment

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Abstract | Salinity and sodicity are the major issues to the sustainability of agriculture in Pakistan. The plants in saline environment are negatively affected due to several issues like low osmotic potential, specific ion effect, and nutritional imbalance. The fertilizer behavior in salt stress conditions is quite different as compared to the normal soils. Linseed is an important oil seed crop. Its 50 % yield reduction occurs at EC_e 5.9 dSm^{-1} and ESP value of 25-30. A field experiment was conducted on saline sodic soils to determine fertilizer requirement of linseed. The selected field was saline sodic in nature with pH value 8.57, medium in extractable K and scarce in P and organic matter. The selected field was sandy loam having 70% sand, 18% silt and 12% clay. The soil was prepared, leveled, and crop was sown with seed rate of 7.5 kg ha^{-1}. Treatments included various rates of NPK {0 (control = T_1), 75 % (T_2), 100 % (T_3), 125 % (T_4), and 150% (T_5) of recommended dose (150-150-75 kg ha^{-1}) of NPK fertilizer). The experimental design was RCBD with three replications. Intercultural operations were performed according to the experimental requirement. At maturity data regarding plant height, capsules/plant and seeds/capsules, 1000 grain weight, number of plants/m length, grain yield, total biomass and harvest index were recorded. All the above parameters were enhanced by increasing fertilizer rate and maximum values were achieved where fertilize was applied at the rate of 210-210-112.5 kg ha^{-1} (150 % of recommended dose i.e., T_5). Grain yield increased more prominently when compared with straw yield where fertilizer was applied @ 210-201-112.5 kg/ha.

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Keywords | Linseed, NPK, Saline sodic soil and yield parameters

Introduction

Due to salt stress, the whole world is facing losses in agriculture productivity. Crop salt tolerance has usually been expressed as the yield decrease expected for high salts content in rhizosphere as compared with yields under non-saline conditions (Jouyban, 2012). Soil degradation is one of the environmental constraints caused by salinity which adversely affects crop productivity and sustainability. In the whole world, 6.5% land is salt affected out of which 50% are saline sodic in nature (FAO, 2008). At least 75 countries in the world are facing the problem of salt affected soils.

Pakistan is predominantly an agricultural country. It is situated within the subtropical region and has semi-arid to arid climate. In Pakistan, agriculture economy is threatened due to saline and waterlogged soils. Salt affected soils account for 6.68 m ha (Ghafoor et al., 2004; Khan, 1998). This salinity causes hyper ionic and osmotic stresses that cause wilting of plants. In arid climatic conditions, salinity is caused due to low rainfall, high evaporation and temperature. The problem of salinity has also increased by accumulation of excess salts in underground water (Ahmad et al., 2014). The metabolic activities and growth of the plants were adversely affected by imbalance and toxic effect of ions like sodium and potassium in saline environment. It also reduced their uptake and translocation (Nawaz et al., 2002).

Salinity is described by the presence of salts in rhizosphere more than the optimum level. It reduces the water uptake by roots due to high osmotic pressure which negatively affects the plant growth. Crop species growing on salt affected lands are adversely affected of dehydration caused by high concentration of sodium and chloride ions. The physiological activities of plants are adversely affected by combined effect of these two mechanisms to such an extent that plant growth becomes impossible resulting ultimately in loss of yield (Ali et al., 2017). The mineral nutrition of plants is affected as well by the higher levels of salinity. In saline soils, the antagonistic effect of Na^+ and Cl^- with K^+, Ca^{2+} and NO_3^- can cause imbalance of nutrients, specific ion toxicity and high Na^+/K^+ ratio that negatively affect the metabolic components of growth (Grattan and Grieves, 2000). This relationship results in excessive buildup of Na^+ and Cl^- in cells which restricts K^+, $Ca^{2+,}$ and Mn^{2+} uptake (Zafar et al., 2019).

Linseed (*Linum usitatissimum* L.) is an important crop cultivated for oil and fiber purposes. It is also named as alsi and flaxseed. Linseed belongs to a family Linaceae and genus Linum. Its origin is Southern Asia and Europe (Casa et al., 1999). In 2016, world production of flax (linseed) was 2.93 million tons lead by Russia with 23% of the global total (FAO, 2017). Main world producers of flax are Russia, France, Belgium and Netherlands and that of linseed is Argentina, USA, Russia, India and Canada. The total world production of linseed and fiber flax has decreased. The average production of linseed in Pakistan is 692 kg ha^{-1} (GOP, 2013). Linseed yield is very low because of less soil fertility, blind use of fertilizers and old cultivation practices. In time sowing and optimum fertilizers use at proper time can improve and persistent linseed yield in Pakistan (Cisse and Amar, 2000). Linseed showed a great response to NP and K application. Nitrogen application along with appropriate amount of phosphorus increases the linseed yield. Adequate nitrogen encourages growth, development and color of the crop (Fageria and Baligar, 2005).

Nitrogen is the constitutional component of protein. Its application accelerates cell division and meristematic activity in the crop due to which quantity, size of cell and quality of fiber is improved. Linseed yield is also increased by increasing nitrogen application (Husain and Zedan, 2008). Excess nitrogen application results in reduction of seed yield by promoting vegetative growth (Ibrahim et al., 2010). Phosphorus is the basic unit of nucleic acids and it plays an essential role in reproductive growth. Due to its involvement in physiological functions, phosphorus is considered essential nutrient for crop production (Jiao et al., 2013). Linseed had a significant response to phosphorus application. In this respect, with the application of phosphorus fertilizer, straw yield was affected as compared to seed yield (Khan et al., 2000). Phosphorus enhanced seed per capsule, capsule/plant and no change in other parameters. Some researchers reported that nitrogen supply along with phosphorus has positive influence on the response of some yield components of linseed (Ahmad et al., 2011). Potassium is essential macronutrient but not a constitutional unit of any plant part. It acts as an enzyme activator and more than 60 enzymatic reactions are under its control which is directly involved in developmental processes such as translocation, photosynthesis, metabolism, respiration, and protein synthesis (Dong et al., 2004). In saline environment, it is competed by sodium ion, which adversely affects the seed and fiber production. Potassium plays an important role in stomata opening, reducing Na^+/K^+ ratio and sodium uptake by plants. It also reduces the osmotic potential in salt affected soil due to which seed and fiber quality and quantity is improved (Oosterhuis, 2001). The objective of the present study was to investigate the combined effect of NPK on linseed at the appropriate applied quantities because the recommended doses for normal soils may not work properly in saline sodic soils.

Materials and Methods

This experiment was conducted to standardize the dose optimization of NPK for linseed crop in saline sodic soils. For site selection, a preliminarily survey was conducted by taking six composite samples from different fields. After analysis, desired field was selected with sandy loam texture having high pH_s, EC_e and SAR (Table 1). The field was prepared, leveled and linseed was sown at field capacity moisture level. The distance between rows was maintained as 30 cm. The test variety was Chandni. Seed rate was 3 kg ha^{-1}. The treatments of experiment were repeated three times applying randomized complete block design (RCBD). The treatments of the experiment are:

T_1= control; T_2= 75% of recommended dose of NPK; T_3= 100% of recommended dose of NPK; T_4 = 125% of recommended dose of NPK; T_5 = 150% of recommended dose of NPK.

Recommended dose of NPK was 150-150-75 kg ha^{-1}. The fertilizers urea, single super phosphate (SSP) and sulphate of potash (SOP) were used as source of NPK. Fertilizer was applied in two steps. At sowing time, phosphorus and potassium fertilizers were applied with half quantity of nitrogen. Remaining half nitrogen was applied to plants with first irrigation. At maturity crop was harvested. Data regarding various agronomic parameters like grain yield, straw yield, plant height, grains/pod, pods/plant, total biomass and weight of 1000 grain were recorded. Plant samples of linseed were shifted in the laboratory and oven dried. Then samples were ground for further chemical analysis.

Table 1: *Original soil analysis.*

Parameters	Values	Units
pH_s	8.57	-
EC_e	5.14	dS/m
Total soluble salts	54.5	Milli equivalents/Liter
Calcium + Magnesium	7.4	me/L
Sodium	47.1	Milli equivalents/Liter
SAR	24.48	-
Organic matter	0.46	%
Available P	8.20	µg/g
Extractable K	107.0	µg/g
Sand	70	%
Silt	18	%
Clay	12	%
Soil texture	Sandy loam	-

Statistical analysis

Fischer's Analysis (F-Test) was employed using Statistics 8.1 software program for the statistical analysis of the collected data. The comparison among fertilizer rates was checked by least significant difference (LSD) test at 5% level of probability.

Results and Discussion

Plant height of linseed

Plant height is a key feature of the plant development which affect overall growth rate of plants. Applied fertilizers significantly affect plant height of crops. The effect of various fertilizer rates on plant height of linseed is given in Figure 1. The plant height of linseed was affected significantly with different rates of NPK application in saline sodic soil. The height of linseed plants varied from 42.8 cm to 88 cm. The treatment T_5 performed best with a value of (88 cm). The treatment T_5 differed non-significantly with T_4 where NPK was applied @ 175-175-93.75 kg ha^{-1}, and significantly differed when compared with control. Similarly, treatment T_3, T_2 and T_1 varied significantly when compared with each other and the control. The lowest value of plant height of linseed (42.8 cm) was noticed in control. Ali et al. (2011) also found that nitrogenous fertilizer enhanced growth parameters of the plants.

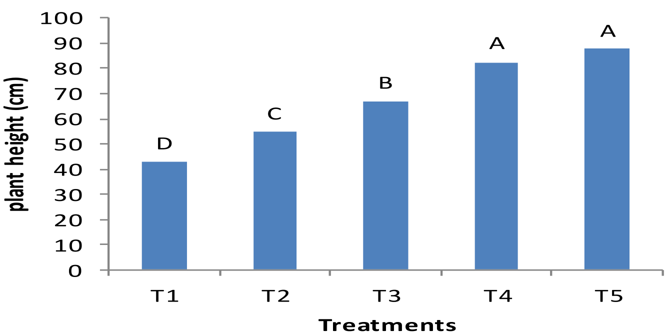

Figure 1: *Effect of NPK on linseed plant height.*

Number of plants/m² of linseed

Number of plants m^{-2} row length of linseed affected by fertilizer application is given in Figure 2. The number of plants m^{-2} row length of linseed was affected significantly with different rates of NPK application in soil. Number of plants m^{-2} row length of linseed varied from 28 to 50 ha^{-1}. The treatment T_5 where fertilizer was applied @ 210-210-112.5 kg ha^{-1} performed the best with the value of 50 and remained superior when compared with T_3, T_2 and T_1. The treatment T_1 with value of 28 remained the inferior most statistically. These findings favour the observations of Khan et al. (2000) because they also observed that fertilizer in the saline sodic soil increased agronomic parameters of linseed.

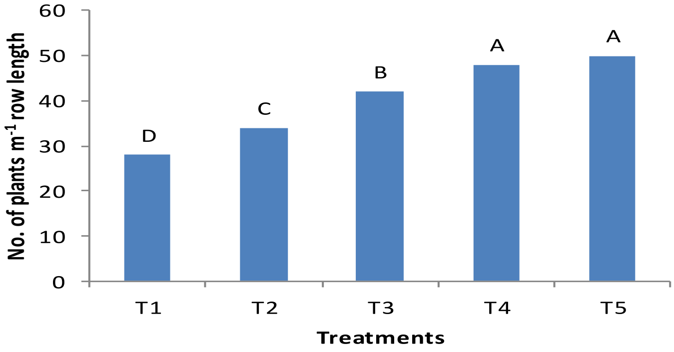

Figure 2: *Effect of NPK on number of plantsm^{-2}.*

Weight of 1000 linseed grains

This parameter of the plant represents the seed yield of the crop. The effect of various fertilizer rates on 1000 grain weight of linseed is given in Figure 3. The 1000 grain weight of linseed was affected significantly with different rates of NPK application in saline sodic soil which varied from 6.98 g to 4.90 g. The treatment T_5 performed the best with a value of 6.98 g. Treatment T_5 differed non-significantly with T_4 where NPK was applied @ 175-175-93.75 kg ha^{-1}, and significantly with T_1. The treatments T_3, T_2 and T_1 varied significantly when compared which each other and the control. The lowest value of 1000 grain weight of linseed (4.90 g) was noticed in control treatment where no fertilizer was applied. These results are supported by the conclusions of Ali et al. (2013). They observed that more NPK consumption enhanced growth parameters of the plants.

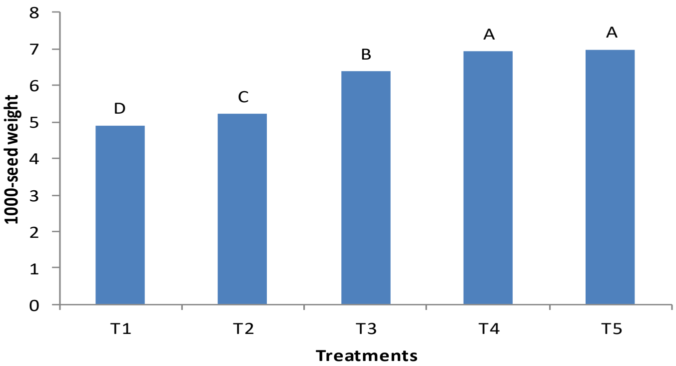

Figure 3: *Effect of NPK on weight of 1000 grains.*

Grain yield of linseed

Linseed is commonly produced in Pakistan for the purpose of oil and fiber. The grain yield directly affects the oil production and inversely affects the fiber production of the crop. The effect of various fertilizer rates on grain yield of linseed is given in Figure 4. It varied from 0.783 to 0.225 t ha^{-1}. The treatment T_5 performed best with a value of 0.783 t ha^{-1}. Treatment T_5 differed non-significantly with T_4 where NPK was applied @ 175-175-93.75 kg ha^{-1}. Treatments T_3, T_2 and T_1 varied significantly when compared which each other and the control. The lowest value of grain yield of linseed (0.225 t ha^{-1}) was noticed in treatment T_1 where fertilizer was applied. Similar results were recorded by Marisol et al., (2009). They claimed improved growth with nitrogen application.

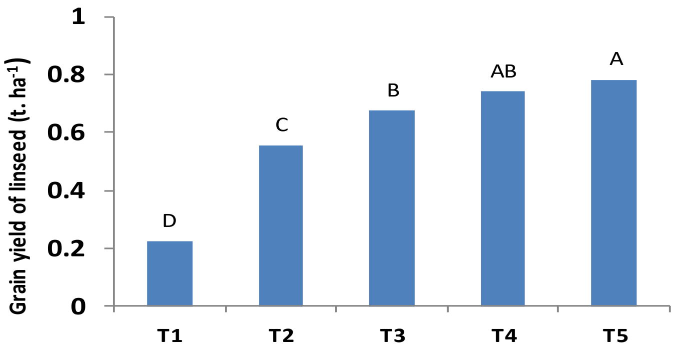

Figure 4: *Effect of NPK on linseed grain yield.*

Number of capsules/plants of linseed

Effect of various rates of NPK on number of capsules per plant of linseed is given in Figure 5. The number of capsules/plants of linseed was affected significantly with different rates of NPK application in saline sodic soil. This parameter of linseed varied from 26 to 49. The treatment T_5 where fertilizer was applied @ 210-210-112.5 kg ha^{-1} performed the best with the value of 49 and but remained superior when compared with control where no fertilizer was applied. It differs significantly with T_3, T_2 and T_1 and non-significantly with T_4. Treatment T_1 (26) remain the most inferior among all the treatments and varied significantly with all other treatments when compared statistically. The observations of Shabaan et al. (2012) that capsules/ plant improved with increasing potassium levels using potassium sulphate as a source supports our findings.

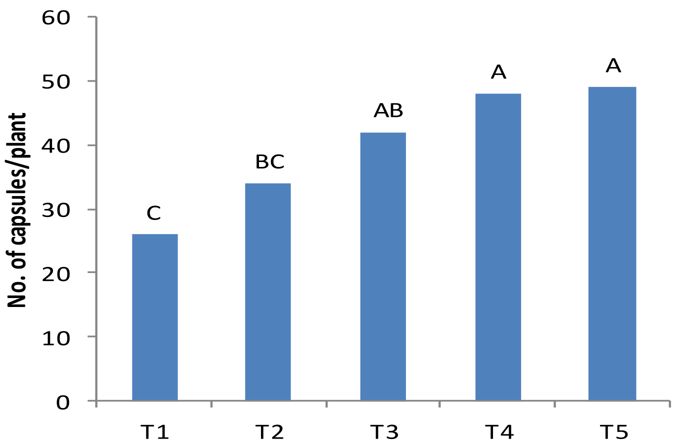

Figure 5: *Effect of different rates of NPK on number of capsules/ plant of linseed.*

Number of seeds per plant of linseed

Effect of various fertilizer rates on number of seeds/plant of linseed is given in Figure 6. The number of seeds/capsules of linseed was affected significantly with different rates of NPK application in saline sodic soil. The number of seeds/capsules of linseed varied from 4.0 to 7.6. The treatment T_5 where fertilizer was applied @ 210-210-112.5 kg ha^{-1} performed the best with the value of 7.6 and remained superior when compared with control where no fertilizer was applied. It differed significantly with T_3, T_2 and T_1 and non-significantly with T_4. Treatment T_1 remained inferior among all the treatments and varied significantly with all other treatments when compared statistically. The observations of Shabaan et al. (2012) that capsules/plant improved with increasing potassium levels using potassium sulphate as a source supports our findings.

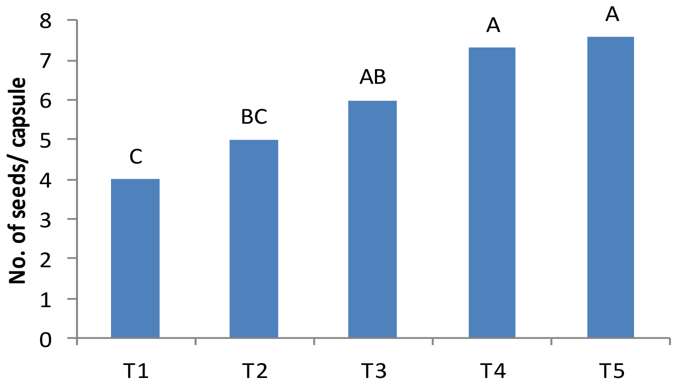

Figure 6: *Effect of NPK on number of seeds/capsule .*

Total biomass of linseed

Effect of various fertilizer rates on total biomass of linseed is given in Figure 7. The total biomass of linseed was affected significantly with different rates of NPK application in saline sodic soil. The total biomass of linseed varied from 0.90 to 2.95 t ha^{-1}. The increasing rates of NPK application significantly affect total biomass. The treatment T_5 with maximum value of (2.95 t ha^{-1}) total biomass applied with fertilizer @ 210-210-112.5 kg ha^{-1} remained superior and it was 228 % higher than control (T_1) while remained at par with T_4. The lowest value of total biomass of linseed (0.9 t ha^{-1}) was recorded in T_1 (control) where fertilizer was not applied at all. According to the observations of Singh et al. (2013) and Lal et al. (2011) were also that total biomass of linseed increased with improving fertility levels and seed rates.

Harvest index of linseed

Various fertilizer rates significantly affect harvest index of linseed (Figure 8). The harvest index of linseed varied from 25.00 t ha^{-1} to 26.54 t ha^{-1}. The increasing rates of NPK application enhanced harvest index. The treatment T_5 with a value (26.54 t ha^{-1}) performed the best when fertilizer was applied @ 210-210-112.5 kg ha^{-1}. The treatment T_5 varies non-significantly with T_4 and differs significantly with all other treatments when compared significantly. Minimum harvest index of linseed (25.00 t ha^{-1}) was recorded in control where fertilizer was not applied. These results are supported by the observations of Singh et al. (2013) who reported that increase in fertility levels enhanced the entire yield of a crop.

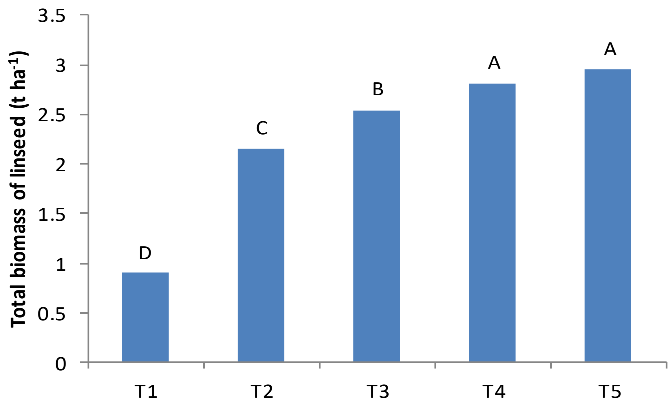

Figure 7: *Effect of NPK on total biomass of Linseed.*

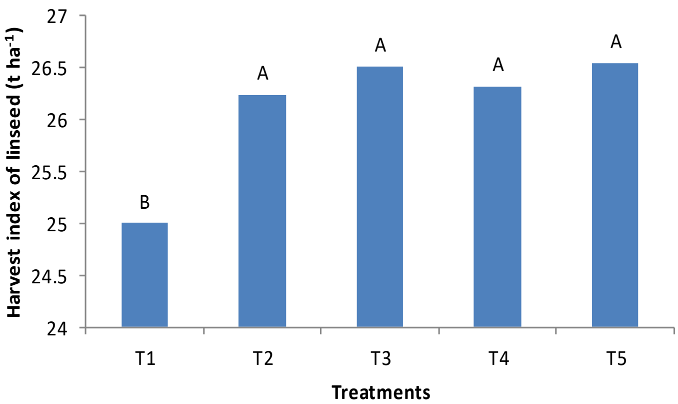

Figure 8: *Effect of NPK on harvest index of Linseed.*

Conclusions and Recommendations

It was concluded from the present results that the increasing rates of fertilizer significantly affect the agronomic parameters of linseed. Maximum parameters were enhanced by increasing fertilizer rate and maximum yield was achieved where fertilize was applied @ 210-210-112.5 kg ha^{-1} (150 % of recommended dose).

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Author's Contribution

Ayesha Zafar: Conception and design of the work, Conduction of experiment and write up.
Ghulam Sarwar: Academic Supervisor and guided throughout the research tenure.
Muhammad Sarfraz: Co-supervision, Interpretation of data and proof reading.
Muhammad Zeeshan: Member of research group and helped in laboratory analysis.
Sher Muhammad: Contributed in statistical analysis.
Ghulam Murtaza: Member of research group and helped in data collection.

Conflict of interest
The authors declare that they have no conflict of interest.

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