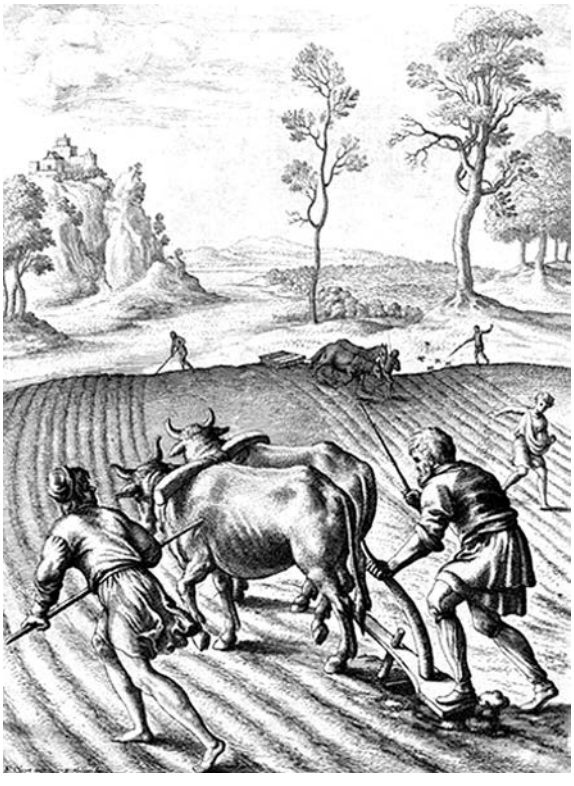
ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

# JOURNAL OF AGRONOMY



ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 5 (2): 251-256, 2006
ISSN 1812-5379


# Effects of Soil and Foliar Application of Different Concentrations of NPK and Foliar Application of $(NH_4)_2SO_4$ on Different Yield Parameters in Wheat

[1]Zafar Jamal, [2]Muhammad Hamayun, [1]Nadeem Ahmad and [1]M. Fayyaz Chaudhary
[1]Department of Biological Sciences, Quaid-e-Azam University, Islamabad, Pakistan
[2]Government Degree College Kotha, Swabi, NWFP, Pakistan

**Abstract:** An experiment was designed and conducted in order to evaluate the effect of different concentrations of nitrogen, phosphorus and potassium (NPK) i.e., $NH_4NO_3$, $K_2HPO_4$ and $KH_2PO_4$ on the yield parameters of Wheat when applied both through foliage and soil. The effect of $(NH_4)_2SO_4$ through foliar application on the same plant was also studied. The grain yield increased in treatments where NPK was applied both through foliar sprays and soil. Soil application of fertilizer yield better results than foliar sprays of NPK in Wheat. Application of $(NH_4)_2SO_4$ failed to show any significant increase in yield although its application enhanced the growth of wheat plant.

**Key words:** Foliar application, soil application, NPK, yield parameters, wheat

## INTRODUCTION

Foliar application refers to the spraying on leaves of growing plants with suitable fertilizer solutions. These solutions may be prepared in different concentration and the plant can be supplied with single or a combination of nutrients. It has been well established that all plant nutrients are absorbed through the leaves of plants and this absorption is remarkable rapid for some nutrients.

In aerial spray, solutions of both macronutrients (N and P) and micronutrients (Zn, Cu, Fe, B and Mo) are used. In many cases, aerial spray of nutrients is preferred and gives quicker and better results than the soil application of chemical fertilizers. Under such conditions when the quick supply of nutrients is obviated or the soil conditions are not conducive for the absorption of nutrients, foliar application may be a preferred solution. The method of foliar application is useful only in those crop plants that are tolerant to aerial spray and are not damaged by this treatment. Examples of tolerant plants are orchard and forest trees, cereal crops like wheat, maize, rice and barley, oil seed crops, potato, tomato, sugar beet and many other vegetables (Kochhar and Krishnamoorthy, 1988). In young leaves the nutrient solution is absorbed through minute hairs (trichomes) on the leaf surface. Some absorption through the stomata is possible and probably does take place but this is not the major pathway. Most of the absorption by the leaf takes place by diffusion through the cuticle (Salisbury and Ross, 1985).

Most commonly deficient elements in the soil are nitrogen, phosphorus and potassium. Nitrogen is an essential constituent of proteins, nucleic acids and many other organic molecules (e.g., chlorophyll) and thus plays an important role in plant life. Being essential for the formation of protoplasm, which is predominantly proteinaceous, the deficiency of nitrogen affects cell division, cell enlargement, chlorophyll content and the respiratory rate.

Phosphorus is absorbed in the form of phosphate ions, $H_2PO^-_4$ and $HPO^-_4$. It is an essential constituent of lipo protein membranes of cell, nucleoproteins, many co-enzymes and organic molecules such as ADP, ATP and NADP which play an important role in the energy transfer reactions of cell metabolism and in oxidation, reduction reactions. (Kochhar and Krishnamoorthy, 1988). It is also necessary for the functioning of mitochondria, which are the centers of cellular respiration.

Potassium, in spite of the fact that it does not enter into the composition of any organic compound in the plant body, it is needed by the plant in large quantities. Its probable role is to provide the necessary ionic background which is in some way indispensable for the maintenance of the living entity of the protoplasm. It plays a crucial role in the plant metabolism. This is due perhaps to its role as an activator of many plant enzymes.

Wheat (*Triticum aestivum* L.) belongs to the Poaceae family. In Pakistan it is called Kanak (Punjabi), Ghanum (Pashto) and Gandum (Urdu). In Pakistan, wheat is the most important single crop. During the 10 years period

**Corresponding Author:** Dr. Muhammad Hamayun, Lecturer, Government Degree College Kotha, Swabi, NWFP, Pakistan

from 1982-83 to 1991-92, it was planted on 37% of the cropped area of the country. During the period from 1980-81 to 1984-85, wheat was planted on about 7.2 million hectare annually, with an average yearly production of 11.6 million tones and average yield of 1596 kg $ha^{-1}$. (Agricultural Statistics of Pakistan 1991-92).

The main objectives of the present investigation were to study the individual effect of foliar applied nutrients i.e., NPK and soil applied nutrients i.e., NPK in wheat, also to study the combined effect of foliar + soil applied nutrients i.e., NPK in wheat and ultimately to study the effects on growth and yield.

## MATERIALS AND METHODS

An experiment was designed and conducted at the Department of Biological Sciences, Quaid-i-Azam University, Islamabad during 2001 in order to evaluate the effects of soil and foliar application of different concentrations of NPK and foliar application of $(NH_4)_2$ $SO_4$ on different growth parameters in wheat (*Triticum aestivum* L.).

Seeds of an approved wheat variety Margallah 99 were procured from Crop Sciences (Wheat Programme) National Agriculture Research Center, Islamabad.

Clay pots of 27.75 cm height and 25.62 cm diameter were used for the experiment. The pots were then filled with sandy loam soil, each pot receiving 10 kg of soil. A representative random sample was taken out for physical and chemical analysis.

**Soil analysis:** Soil texture was determined by Bouycous (1962) hydrometer method (Bouycous, 1962). Nitrogen was analysed through Kjeldahl method (Paul and Berry, 1921). Ammonium bicarbonate-Diethylen triamin penta acetic acid (AB-DTPA) method was adopted to analyse potassium and phosphorus (Soltanpour and Woekman, 1979).

**Seed selection:** Five healthy seeds per pot were sown at a distance 5 cm from one another on 17th November 2000. 50% germination was achieved after 10 days of sowing on 27th November 2000.

**Preparation of stock solution:** Solutions of required concentration of $KH_2PO_4$ and $K_2HPO_4$ were prepared and then mixed to form potassium-phosphate buffer with a pH of 7.0 and then $NH_4NO_3$ was added to the mixture. This pH of 7.0 was maintained through out the study. $NH_4NO_3$ was used as a nitrogen source, $K_2HPO_4$ was used as phosphorus source and $KH_2PO_4$ was used as a K source.

**Fertilizer concentrations used**:

- Foliar application of NPK
  1st Concentration ($C_1$) = 2% N, 1% P, 2% K (Min.)
  2nd Concentration ($C_2$) = 3% N, 2% P, 3% K (Opti.)
  3rd Concentration ($C_3$) = 4% N, 3% P, 4% K (Max.)
- Soil application of NPK:
  2nd Concentration ($C_2$) = 3% N, 2% P, 3% K (Opti.)
- Foliar application of $(NH_4)_2$ $SO_4$:
  2nd Concentration = 3% $(NH_4)_2$ $SO_4$

**Strategy of fertilizer application:** Fertilizer application was carried out at three different growth stages of wheat plant as planned. These growth stages were:

- Seedling Stage:
  This stage was reached 20 days after mean germination.
- Juvenile Stage:
  This stage was reached 60 days after mean germination.
- Pre-flowering Stage:
  This stage was reached 100 days after mean germination.

Different treatments received fertilizer doses once, twice and thrice i.e., for seedling stage, juvenile stage and pre-flowering stage respectively. Foliar application of NPK and $(NH_4)_2SO_4$ was carried out after 20 days 60 days and 100 days from mean germination.
The data was recorded for the following parameters.

- Number of fertile tillers/plant.
- Spike length of main tiller (cm).
- Spike diameter of main tiller (cm).
- Awn length (cm).
- Spike weight of main tiller (g).
- Number of grains/spike.
- 1000-grains weight (g).

**Statistical analysis**: Data for all parameters was analyzed statistically by adopting analysis of variance techniques. The technique of One Factor Randomized Complete Block Design was used for this purpose. The mean values of all the treatments were compared by applying Duncan's Multiple Range Test.

**Labels used in the experiment:**

T1 = $C_o$ = Control
T2 = $T_1C_1t_1$ = Foliar application + Concentration 1 + Single Fertilizer dose ($NH_4NO_3 + KH_2PO_4 + K_2HPO_4$)
T3 = $T_1C_1t_2$ = Foliar application + Concentration 1 + double fertilizer dose
T4 = $T_1C_1t_3$ = Foliar application + Concentration 1 + triple fertilizer dose
T5 = $T_1C_2t_1$ = Foliar application + Concentration 2 + single fertilizer dose
T6 = $T_1C_2t_2$ = Foliar application + Concentration 2 + double fertilizer dose
T7 = $T_1C_2t_3$ = Foliar application + Concentration 2 + triple fertilizer dose
T8 = $T_1C_3t_1$ = Foliar application + Concentration 3 + single fertilizer dose
T9 = $T_1C_3t_2$ = Foliar application + Concentration 3 + double fertilizer dose
T10 = $T_1C_3t_3$ = Foliar application + Concentration 3 + triple fertilizer dose
T11 = $T_2C_2t_1$ = Soil application + Concentration 2 + single fertilizer dose ($NH_4NO_3 + KH_2PO_4 + K_2HPO_4$)
T12 = $T_2C_2t_2$ = Soil application + Concentration 2 + double fertilizer dose
T13 = $T_2C_2t_3$ = Soil application + Concentration 2 + triple fertilizer dose
T14 = $T_3C_{1.2}t_1$ = Foliar + Soil application + Conc. 1 for F and 2 for S + single fd. ($NH_4NO_3 + KH_2PO_4 + K_2HPO_4$)
T15 = $T_3C_{1.2}t_2$ = Foliar + Soil application + Conc. 1 for F and 2 for S + double fd.
T16 = $T_3C_{1.2}t_3$ = Foliar + Soil application + Conc. 1 for F and 2 for S + triple fd.
T17 = $T_3C_{2.2}t_1$ = Foliar + Soil application + Conc. 2 for F and 2 for S + single fd.
T18 = $T_3C_{2.2}t_2$ = Foliar + Soil application + Conc. 2 for F and 2 for S + double fd.
T19 = $T_3C_{2.2}t_3$ = Foliar + Soil application + Conc. 2 for F and 2 for S + triple fd.
T20 = $T_3C_{3.2}t_1$ = Foliar + Soil application + Conc. 3 for F and 2 for S + single fd.
T21 = $T_3C_{3.2}t_2$ = Foliar + Soil application + Conc. 3 for F and 2 for S + double fd.
T22 = $T_3C_{3.2}t_3$ = Foliar + Soil application + Conc. 3 for F and 2 for S + triple fd.
T23 = $T_4C_2t_1$ = Foliar application + Conc. 2 + single fertilizer dose $(NH_4)_2SO_4$
T24 = $T_4C_2t_2$ = Foliar application + Conc. 2 + double fertilizer dose
T25 = $T_4C_2t_3$ = Foliar application + Conc. 2 + triple fertilizer dose

## RESULTS

**Soil analysis:** The results showed that the soil used in the experiment was of sandy loam in texture. Chemical analysis showed the pH, EC and N, P, K values. Nitrogen, and phosphorous were found deficient in the soil samples (Table 1) as compared to standard values (Soltanpour, 1985).

**Yield parameters:** Number of fertile tillers per plant showed an increase in treatments where nutrients were applied both through foliage and soil. Maximum mean value was recorded from (T22) $T_3C_{3.2}t_3$ i.e., 4.667. Number of tillers actually determines the yield of crop, so foliar + soil application gave positive results in increasing yield of crop. However foliar application gave lower values on average than soil application (Table 2). The results obtained are in accordance with those of Salwau (1994). Ramamoorthy *et al.* (1995) recorded similar results in black gram and by Ahmed and Mohammad (1991) in apple. According to Growada and Growada (1980), number of pods/plant increased with NPK application in *Vigna radiata*. However, Ghildiyal (1992) found that foliar application increased number of pods in the same plant. This difference might be due to the requirement of different plant of nutrient status of that soil. After foliar + soil the best results were shown by soil application treatments. These results are in line with those of Singh and Kamath (1989) who reported that foliar application was not superior to soil or basal application. Higher basal fertilizer dose was effective (Nafees *et al.*, 1993).

The data obtained for mean spike length per plant revealed that foliar + soil applied treatments gave maximum values on average. The maximum mean value for spike length was recorded from (T22) $T_3C_{3.2}t_3$ i.e., 13.67 cm (Table 2). The results are in accordance with those of Salwau (1994) who recorded a significant increase in spike length with the application of 75 Kg/fed N to the soil. The results are also in line with the finding of Bolland *et al.* (1999), Sattar (1973) and Awady *et al.* (1993) who noted an increased yield response with the increase in fertilizer application.

The results obtained for spike diameter also showed higher values in treatments involving foliar + soil application. Maximum value of 1.667 cm was recorded from (T19) $T_3C_{2.2}t_3$ (Table 2). The results are in line with those of Salwau (1994), Bolland *et al.* (1999), Sattar (1973)

Table 1: Chemical analysis of two soil samples showing the mount of NPK in mg $kg^{-1}$ in soil

| pH | Ece (dS $m^{-1}$) | K | $NO_3$-N | P |
|---|---|---|---|---|
| 7.32 | 0.93 | 70 | 0.68 | 0.84 |
| 7.33 | 1.39 | 64 | 0.76 | 0.84 |

Table 2: Effect of different treatments on mean values of number of fertile tillers/plant, spike length, spike diameter and awn length in wheat

| Treatments | Fertile tillers/plant | Spike length (cm) | Spike diameter (cm) | Awn length (cm) |
|---|---|---|---|---|
| T1 | 2.000FGH | 10.60GHI | 1.033GHI | 6.233F-K |
| T2 | 2.333EFG | 10.23I | 1.067F-I | 7.800BCD |
| T3 | 2.333EFG | 11.37D-I | 1.000HI | 5.867G-K |
| T4 | 2.333EFG | 11.13E-I | 1.133E-H | 6.467E-J |
| T5 | 1.667GH | 10.23I | 1.033GHI | 5.267JK |
| T6 | 1.000H | 11.60D-I | 1.067F-I | 6.600D-I |
| T7 | 2.333EFG | 10.53GHI | 1.200EFG | 5.87 -K |
| T8 | 3.000C-F | 10.73F-I | 1.167E-H | 6.833D-G |
| T9 | 2.333EFG | 11.93D-G | 1.067F-I | 6.333F-J |
| T10 | 1.667GH | 11.97D-G | 1.167E-H | 5.833G-K |
| T11 | 2.333EFG | 12.10C-F | 1.167E-H | 7.633B-E |
| T12 | 3.667A-D | 13.50ABC | 1.467BC | 6.333F-J |
| T13 | 4.333AB | 13.53AB | 1.233DEF | 6.233F-K |
| T14 | 4.333AB | 11.70D-H | 1.233DEF | 7.433B-F |
| T15 | 4.667A | 12.57A-E | 1.400BCD | 8.133ABC |
| T16 | 4.333AB | 12.13B-F | 1.500B | 9.033A |
| T17 | 3.667A-D | 10.33HI | 1.067F-I | 6.667D-H |
| T18 | 4.000ABC | 10.90F-I | 1.133E-H | 5.333IJK |
| T19 | 4.000ABC | 12.83A-D | 1.667A | 8.633AB |
| T20 | 3.333B-E | 11.83D-G | 1.167E-H | 7.200C-F |
| T21 | 3.667A-D | 12.50A-E | 1.467BC | 6.400E-J |
| T22 | 4.667A | 13.67A | 1.300CDE | 7.667D-E |
| T23 | 2.667D-G | 11.97D-G | 0.9333I | 5.667G-K |
| T24 | 2.333EFG | 11.03F-I | 0.9333I | 4.967K |
| T25 | 2.333EFG | 12.80A-D | 1.133E-H | 5.467H-K |
| LSD at 5% | 1.059 | 1.230 | 0.1642 | 1.098 |

Table 3: Effect of different treatments on mean values of spike weight of main tiller, No. of grains/spike and 1000-grain weight in wheat

| Treatment | Spike weight (gm) | No. of Grains/ Spike | 1000 Grain weight (gm) |
|---|---|---|---|
| T1 | 1.337N | 30.67L | 10.33Q |
| T2 | 2.663J | 35.00KL | 13.33N |
| T3 | 1.520N | 48.33C-H | 13.33N |
| T4 | 2.050L | 45.67D-J | 12.33O |
| T5 | 1.450N | 41.00H-K | 11.33P |
| T6 | 2.707IJ | 41.00H-K | 13.33N |
| T7 | 2.650J | 43.33E-K | 20.33H |
| T8 | 1.793M | 36.33KL | 16.33K |
| T9 | 2.103L | 42.00H-K | 15.33L |
| T10 | 2.273KL | 43.00F-K | 12.33O |
| T11 | 2.333K | 40.00H-K | 22.33G |
| T12 | 4.737B | 42.33G-K | 24.33G |
| T13 | 4.087D | 47.67C-H | 17.33J |
| T14 | 4.330C | 47.33C-I | 32.33B |
| T15 | 3.850E | 51.33B-F | 41.33A |
| T16 | 2.927HI | 51.67B-E | 31.33C |
| T17 | 2.707IJ | 39.00IKL | 18.00IJ |
| T18 | 2.900HI | 50.67B-G | 22.33G |
| T19 | 5.367A | 58.00B | 26.33E |
| T20 | 3.490F | 52.00BCD | 25.67E |
| T21 | 3.013H | 45.00D-J | 28.33D |
| T22 | 5.283A | 67.33A | 18.33I |
| T23 | 3.270G | 38.33JKL | 14.33M |
| T24 | 2.163KL | 38.33JKL | 11.00PQ |
| T25 | 2.847HIJ | 55.00B | 13.33N |
| LSD at 5% | 0.2077 | 7.244 | 0.8225 |

and Awady *et al.* (1993). Foliar + soil applied treatments showed higher values when compared with either control or only the foliar application. Soil application treatments gave slightly higher value.

The data obtained for awn length showed that foliar + soil applied treatments gave higher values on average (Table 2). An increased awn length was observed in the spikes of longer length. So awn length may be related with the spike length or in other words with yield. On this basis the results obtained are in accordance with those of El-Defan *et al.* (1999).

During the study, maximum mean value for spike weight of main tiller was recorded from (T19) $T_3C_{2.2}t_3$ i.e., 5.367 g. Foliar + soil applied treatments showed higher values on average followed by soil applied treatments. However, foliar applied treatments showed lower values

on average (Table 3). The results are in compliance to those of Salwau (1994). Other investigators obtained the same results such as Bolland *et al.* (1999), Mahadkar and saraf (1988) and Growada and Growada (1980).

The results obtained for number of grains per spike showed that foliar + soil applied treatments gave higher values on average. Number of grains per spike actually determines the yield of crop (Table 3). The results are in line with the findings of Salwau (1994) who reported that there was a significant increase in number of grains per spike when 75 kg $fed^{-1}$) nitrogen was added to the soil. Bolland *et al.* (1999) observed that wheat produced very large yield responses to increasing application of phosphorus. The application of NPK increased seed yield by 58%. (Khalil and Khalifa 1999). Growada and Growada (1980) also obtained the same results with NPK on *Vigna radiata*. Lixandru *et al.* (1985) observed that basal application of 69 Kg N, 60 Kg $P_2O_5$ gave increased yield in *phoseolus bulgaris* L. The results could also be confirmed by those of Ramamoorthv *et al.* (1995), Pandrangi *et al.* (1991) and Vakhmistrov and Fedorov (1983).

During the study higher 1000-grain weight was obtained from foliar + soil applied treatments on average (Table 3). The results are in accordance with those of El-Defan *et al.* (1999) who found that soil + foliar treatments were superior for increasing 1000-grain weight followed by foliar –K treatments. These results are also the confirmation of the findings of Salwau (1994). Dawood (1994) observed that maximum 1000-grain weight was recorded for plants received 10 Kg $P_2O_5$.

## CONCLUSIONS

The results of the present study revealed that foliar application of nutrients along with soil application of nutrients gave higher values in almost all the parameters under discussion. The individual affects of foliar application were not satisfactory with $NH_4NO_3$, $K_2HPO_4$ and $KH_2PO_4$ but foliar application of $(NH_4)_2SO_4$ gave intermediate values i.e., between maximum and minimum. Soil application alone showed the second best results. Foliar application on NPK gave lower values on average. This clearly shows that leaves alone are not potential enough to fulfill the requirements of the plant for nutrients. Efficient root system along with healthy foliage can only serve the purpose. Foliar application of $(NH_4)_2SO_4$ gave intermediate results i.e., between maximum and minimum in most of the cases but in comparison with the control it proved quite beneficial for the wheat plant.

Present research indicates that foliar application of fertilizer cannot be justified under conditions where physicochemical properties of soil are good enough for the uptake of nutrients from soil. However, it is important to note that under conditions, where nutrients supply to plants become a limiting factor because of soil properties, foliar application can serve a useful purpose in by passing the soil to ensure optimal supply of nutrients to plants.

## REFERENCES

Agricultural Statistics of Pakistan, 1991-92. Ministry of Food, Agriculture and Livestock Division, Government of Pakistan.

Ahmed, F.F. and M.A. Mohamed, 1991. Behavior of Anna, a newly introduced apple cultivar, under different rates and methods of nitrogen application. Ann. Agric. Sci. Moshtohor, 29: 497-512.

Awady, R.M.E., E.N. Gendy and S.Y. Montaser, 1993. Effect of phosphate and zinc application on lentil plants and some chemical composition of alluvial soils. Egypt. J. Agri. Res., 71: 873-882.

Bolland, M.D.A., K.H.M. Siddiqui, S.P. Loss and M.J. Baker. 1999. Comparing responses of grain legumes, wheat and canda to application of superphosphate. J. Nut. Cycl. Agroeco. Aus., 53: 157-175.

Bouycous, G.J., 1962. Hydrometer method improved for making particle size analysis of soil. Agron., J., 54: 464-465.

Dawood, R.A., 1994. Hand weeding in lentil (*Lens culinaris* Medic.) grown on beds at various growth stages under different phosphorus levels. Assiut. J. Agric. Sci., 25: 131-142.

El-Defan, T.A.A., H.M. A. El-Kholi, M.G.M. Rifaat and A.E.A. Allah, 1999. Effect of soil and foliar application of potassium on yield and mineral content of wheat grains grown in sandy soils. Egypt. J. Agric. Res., 77: 513-522.

Ghildiyal, M.C., 1992. Effect of urea on photosynthesis and yield in mung bean. J. Agron. Crop. Sci., 168: 91-94.

Growada, S.T. and K.T.K. Growada, 1980. Influence of fertilizer on yield component of green gram. Ind. J. Agron., 23: 374.

Khalil, N.A. and R. Khalifa, 1991. Response of lentil (*Lens culinaris* Medic.) growth and yield to macro and micronutrient application. Bull. Fac. Agric. Univ. Cairo, 42: 701-712.

Kochhar, P.L. and H.N. Krishnamoorthy, 1988. A Text Book of Plant Physiology, pp: 174, 175, 165-168, 179, 180.

Mahadkar, U.V. and C.S. Saraf, 1988. Effects of various inputs on fertilizer nitrogen utilization and yield of black gram and green gram and their residual effect on succeeding fodder sorghum. Fert. News (India), 33: 43-46.

Nafees, A.K., Samiuilah and O. Aziz, 1993. Response of Mustard to Seed Treatment with Pyridioxine and Basal and Foliar Application of Nitrogen and Phosphorus. J. Plant Nutr., 16: 1651-1659.

Pandrangi, R.B., S.G. Wankhade and R.A. Nasre, 1991. Response of mung (*Phaseolus aureus* L.) to soil and foliar application of phosphatic fertilizers. Legume Res., 14: 187-188.

Paul, A.E. and E.H. Berry, 1921. The Kjeldahl method and its modifications. J. Ass. Off. Agric. Chem., 5: 108-132.

Ramamoorthv, K., M. Ramasamv and K.S. Jehangir, 1995. Response of rainfed blackgram (*Phaseolus mungo*) to foliar nutrition of potassium. Ind. J. Agron., 40: 114-115.

Salisbury and Ross, 1985. Plant Physiology. 3rd Edn.

Salwau, M.I.M., 1994. Effect of soil and foliar application of nitrogen levels on yield and yield components of wheat. (*T.aestivum* L.) Ann. Agric. Sci. Moshtohor., 32: 705-715.

Sattar, A., 1973. Relative efficiency of different phosphorus sources in production of mung bean. M.Sc. Thesis. University Faisalabad Pakistan.

Singh, S. and M.B. Kamath, 1989. Relative efficiency of some method of phosphate application in the utilization of P by safflower (*Carthamus tinctorius* L.). J. Nuc. Agric. Biol., 18: 104-108.

Soltanpour, P.N. and S. Woekman, 1979. Modification of the $NH_4HCO_3$-DTPA soil test to omit carbon black. Commun. Sci. Plant Analysis, 10: 1411-1420.

Soltanpour, P.N., 1985. Use of ammonium bicarbonate DTPA soil test to evaluate elemental availability and toxicity. Commun. Sci. Plant. Analysis, 16: 323-338.

Vakhmistrov, D.B. and A.A. Fedrov, 1983. Separate determination of the optimum NPK content and NPK ratio in a fertilizer for Soybean. Yield and Qual. Agrokhim, 4: 3-10.