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Differential Response of *Zea mays* L. in Relation to Weed Control and Different Macronutrient Combinations

(Respons Membeza *Zea mays* Berhubung dengan Kawalan Rumpai dan Gabungan Makronutrien Berbeza)

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ABSTRACT

Time of weed control and fertilizer application usually decide the profitability of crop production. The effects of weed control and macronutrients on maize crop were investigated. The study was undertaken in March 2009, using a RCBD design with split plot arrangements. The experimental set up was established at the Agricultural University Peshawar and seedbeds were prepared with the proper moisture regime. Maize was planted with one plot left weed free for first six weeks while another infested with weed. The combinations of macronutrients used were nitrogen, phosphorus, potassium, nitrogen-phosphorus, nitrogen-potassium, phosphorus-potassium and nitrogen-phosphorus-potassium. Control (no fertilizer) was included for comparison. The observations revealed that when a comparison was made between the application of fertilizers and weed control, the latter proved more important because weed infested plots had no harvestable maize plants. The role of main nutrients in crop production is well known and cannot be left aside, however weed infestation does not provide us a fair choice of fertilizers application. The maximum maize grain yield was recorded under nitrogen-phosphorus combination and promising results were obtained. The weeds and maize benefited equally in terms of fresh and dry weed biomass with an application of fertilizer in particular N singly or together with P. In view of this, application of fertilizer should be changed from broadcast to band and/or placement. In general, a positive interaction was seen between N and P promoting the growth of maize and weeds. It can be said that herbicide application for weed control is important because of the fact that hand weeding is not economical, difficult, time consuming because of perennial weeds and hot weather conditions in the month of June.

Keywords: Macronutrients; maize; NPK; weeds; yield

ABSTRAK

Masa kawalan rumpai dan pemberian baja biasanya akan menentukan keuntungan pengeluaran tanaman. Kesan kawalan rumpai dan makronutrien bagi tanaman jagung telah dikaji. Kajian telah dijalankan pada bulan Mac 2009, menggunakan reka bentuk RCBD dengan perletakan plot pecah. Percubaan telah dilakukan di Universiti Pertanian Peshawar dan batas biji benih telah disediakan dengan regim kelembapan yang sesuai. Jagung telah ditanam dengan dibiarkan bebas rumpai bagi enam minggu pertama sementara satu lagi telah dibiakkan dengan rumpai. Gabungan makronutrien yang digunakan ialah nitrogen, fosforus, kalium, nitrogen-fosforus, nitrogen-kalium, fosforus-kalium dan nitrogen-fosforus-kalium. Kawalan (tanpa baja) telah ditambah untuk perbandingan. Pemerhatian telah menunjukkan bila perbandingan dibuat antara pemberian baja dan kawasan rumpai, yang kemudian telah dibuktikan lebih penting kerana plot yang berumpai tidak mempunyai jagung yang boleh dituai. Peranan nutrien utama dalam pengeluaran tanaman telah diketahui umum dan tidak boleh diabaikan, walau bagaimanapun kewujudan rumpai tidak memberi pilihan kepada pemberian baja. Hasil jagung maksimum telah direkodkan di bawah gabungan nitrogen-fosforus dan hasil yang baik telah diperoleh. Rumpai dan jagung telah mendapat manfaat yang hampir sama daripada segi biojisim rumpai kering dan basah dengan pemberian baja khususnya N secara tunggal atau bersama P. Oleh itu, pemberian baja harus ditukar daripada cara sebaran kepada jalur dan/atau secara perletakan. Umumnya suatu tindak balas positif boleh dilihat antara N dan P dengan meningkatkan pertumbuhan jagung dan rumpai. Ia boleh dirumuskan bahawa pengaplikasian herbisid untuk kawalan rumpai adalah penting kerana membuang rumpai dengan tangan adalah tidak ekonomi, sukar, memakan masa kerana kesakaan rumpai dan keadaan cuaca panas di bulan Jun.

Kata kunci: Hasil; jagung; makronutrien; NPK; rumpai

INTRODUCTION

One of the major crops sown in Pakistan is maize (*Z. mays*). However, the yield on global basis has always remained below the level of industrialized countries. The reasons put forward are poor weed management practices and imbalanced fertilizer doses. The crop is infested with different weeds, as such the production is adversely affected. Many workers have documented the detrimental effects of weeds on crops; in the form of crop reduction, varying between 20-40% which is related to the weed species and its density (Ashique et al. 1997). If control measures are not applied the losses could vary between 35 and 70% (Ford & Pleasant 1994). The weeds resulting in a serious damage of maize crop in Khyber Pakhtunkhwa province are *Convolvulus arvensis* L., *Cynodon dactylon* L., *Cyperus rotundus* L., *Digera muricata* L., *Digitaria sanguinalis* L., *Echinochloa crus-galli* L., *Portulaca oleracea, Sorghum halepense* L., *Trianthema partulacastrum* and *Leptochloa* sp. All these weed taxa compete for nutrients, soil moisture and light with maize resulting in a loss of yield as well as the quality of crop. The presence of these weeds greatly affects the overall production of maize (Khan et al. 2012).

The three major nutrients for crop growth are nitrogen, phosphorous and potassium. They are needed to carry out various physiological functions in plants and finally affect crop yield. N and P are deficient in the soil of the experimental sites. There is thus a need for their application as fertilizer. Out of these nutrients, nitrogen is the most remarkable as regards to its effects on plant growth. It imparts a dark green luxuriant appearance to the growing field crops. Time and dose of nitrogen greatly affected the grain yield of maize (Ciampitti & Vyn 2012) while phosphorus deficiency delays growth of maize, leads to biomass reduction, grain number m^{-2}, as well as 1000 grain weight (Plenet et al. 2000). On the other hand availability of potassium at adequate levels results in better crops. Although there is a sharing of nutrients between weeds and crop plants, but not much work has been done on the interaction of weed control with nitrogen, phosphorus and potassium applied singly or in the form of mixtures (Ali & Rizvi 1993).

Generally plots treated with nitrogen have higher population and biomass of grassy weeds. As against this, application of phosphorus and potassium singly or as mixtures results in a domination of broad-leaved weeds (Das & Yaduraju 1999). Other investigations have shown that studying weed-fertilizer relationships reveals that community composition of the weeds changes due to soil available P in the first place which is followed by light intensity on soil surface (Yin 2005). The results published by Everaarts (2006) clearly enlighten the fact that growth of weeds is stimulated by nitrogen, ground-cover development by phosphorus but weed weight was not affected by potassium. The biomass of weeds is also increased by N application, stressing its importance in weed growth and ability to compete with maize for low sources of soil N (Azeez 2009). Phosphorus deficiency decreases agricultural productivity on more than two billion hectares worldwide (Oberson et al. 2001). Fertilizer application positively affected the maize and several perennial weeds of maize (Umm-e-Kulsoom et al. 2012). The farmers in the maize growing areas give much importance to fertilizer application as compared to weed control. Thus fertilizer application without weed management accelerates the growth of weeds which better compete with the maize plants. The aim of this study was to investigate the effect of N, P and K alone and in mixtures on the grain yield of maize under weed free and weed infested conditions.

Materials and Methods

The experiments were carried out at the University of Agriculture Peshawar, Pakistan in spring 2009. The soil at the study site was silty-clayey-loam (40% clay, 51.3% silt and 8.7% sand) with 8.02 mean soil pH (Bhatti 2002). The RCB (randomized complete block) system was followed with split plot arrangement, with one plot having weeds throughout the crop season and second plot with no weeds for the first six weeks. The macro-nutrient treatments given were eight; N (Nitrogen), (Phosphorus) P, (Potassium) K, N- P, N- K, P- K and N- P- K. Control (0 NPK) was included in each main plot for comparison. The recommended rates of the macro nutrients were applied as per treatment detail after preparing seedbeds with proper moisture condition. The seeds maize hybride (32T78 - Pioneer) were sown in the first week of March 2009 using drill method. The distance between the rows and plants was maintained at 75 cm and 30 cm, respectively. There were eight rows in each treatment. N, P and K were applied at 120, 100 and 60 kg ha^{-1}. The source of these was urea, single super phosphate and potash, respectively. Seeds were sown at the rate of 20 kg ha^{-1}. The irrigation of crop was done per requirement. During the experiment standard agronomic practices were followed as per treatments mentioned above.

DATA COLLECTION AND STATISTICAL ANALYSIS

Density of the weeds (m^{-2}), fresh/dry biomass of weeds (gm^{-2}), weight of 500 kernels (g) and yield of the grains (kg ha^{-1}) was recorded.

PROCEDURE OF DATA RECORDING

Weed density (m^{-2}) was recorded 60 days after sowing (DAS). Three places were selected at random in each treatment, weeds inside identified and recorded together with density using 33 × 33 cm quadrate. For each treatment averages were computed and data converted into weed density m^{-2}. The weed fresh/dry weight (g m^{-2}) was recorded after harvesting the weeds in each treatment followed by weighing these and data converted to fresh weed biomass g m^{-2}. These samples were left in oven for 48 h at 65°C and dry biomass noted. For the weight of kernels, 500 kernels (g) were taken at random per treatment. The weight was recorded by using electronic balance. For grain yield (kg ha^{-1}) determination, all plants from each treatment were harvested separately at physiological maturity, cobs were threshed yield for each treatment recorded. Data was converted into kg ha^{-1} by using the following formula:

$$\text{Grain yield}\left(\text{kg ha}^{-1}\right) = \frac{\text{Weight of sample}\left(\text{kg}\right)}{\text{Area harvested}\left(\text{m}^{-2}\right)} \times 10000,$$

The data were analyzed statistically using MSTATC software program with the purpose to determine the significant effect of treatments on weeds and maize. If ANOVA showed a significant difference between treatments LSD test at 5% probability level was applied (Steel & Torrie 1984).

Means of the main plots i.e. weed free (WF)/weed infested (WI) and treatments (fertilizers) were presented graphically while interactions were presented in tabular format.

FIGURE 1. Mean weed density in weed free and weed infested plots

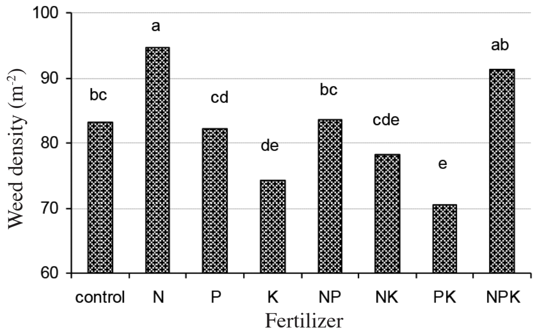

FIGURE 2. Mean weed density in fertilizer treated plots

RESULTS AND DISCUSSION

Means of the weed free (WF)/weed infested (WI) are presented in Figure 1. This data reveals that in the WF and WI plots density (m^{-2}) of weeds was significantly (p<0.05) different. Weeding was done on fortnightly (first six weeks only) basis except when rains delayed the weeding. Therefore many weeds were observed in the weed free plots as there was continuous germination of weed seeds. The results in Figure 2 shows that in N (94 m^{-2}) and NPK (91 m^{-2}) treated plots weed density is maximum, but in PK (70 m^{-2}) and K (74 m^{-2}), minimum weed density was recorded. All other treatment values were intermediate and majority were statistically at par with each other. Looking at the overall means we can say that in nitrogen treated plots weed density is higher than other treatments, which could be attributed to the stimulation of germination in many weed seeds by nitrogen. In N, NP, NK and NPK treatments grassy weed population as well as biomass was higher (Das & Yaduraju 1999).

A perusal of the results on WF/WI and fertilizer reveals a significant interactions between these (Table 1). The weed density was minimum (29.7 m^{-2}) in control under weed free conditions but maximum (152.3 m^{-2}) in N treated plots under weed infested conditions. These results also depict that germination of weed seeds is stimulated by nitrogen application. The weed taxa observed in the plots were; *Cyperus rotundus*, *Leptochloa* sp., *Echinochloa crus-galli*, *Sorghum halepense, Cynodon dactylon*, *Digitaria sanguinalis, Convolvulus arvensis*, *Amaranthus viridis, Digera muricata* and *Portulaca oleracea*. There is a need for more studies on the fertilizer application effects on weed seed germination. The ground-cover development and growth of weeds was stimulated by phosphorus but their growth in the form of ground-cover and weight was

TABLE 1. Effect of different combinations of NPK on weed density, fresh and dry weed biomass

Treatment	Weed density (m^{-2})		Fresh weed biomass (gm^{-2})		Dry weed biomass (gm^{-2})	
	Weed free	Weed infested	Weed free	Weed infested	Weed free	Weed infested
Control	29.7 g	136.7 bc	38.3 f	160.7 e	10.7	43.3
N	37.0 g	152.3 a	45.7 f	221.7 ab	16.0	52.0
P	35.7 g	128.7 cd	42.0 f	204.3 bcd	16.3	46.3
K	33.3 g	115.3 ef	38.7 f	187.7 d	17.0	42.7
N plus P	39.0 g	128.0 cd	44.3 f	208.3 abc	21.3	62.7
N plus K	33.7 g	123.0 de	42.7 f	199.0 cd	19.3	45.7
P plus K	30.0 g	111.0 f	40.7 f	207.0 abc	16.7	43.7
N plus P plus K	37.0 g	145.7 ab	46.3 f	223.0 a	21.3	55.3

DAS=Days after sowing
LSD value for weed density = 11.91
LSD value for fresh weed biomass = 18.52

stimulated by nitrogen as reported by Everaarts (2006) as well. The instant results revealed that weed removal up to six weeks in maize is enough to avoid its competition with maize as only few weeds were recorded with lower biomass.

FRESH WEED BIOMASS (g m^{-2})

Perusal of the data presented in Figure 3 indicated that in WF/WI plots fresh weed biomass (g m^{-2}) differed significantly. Weeding decreased their density and biomass because of the fortnightly weeding schedule. A decrease in the biomass of weeds is expected to affect the maize grain yield directly and positively.

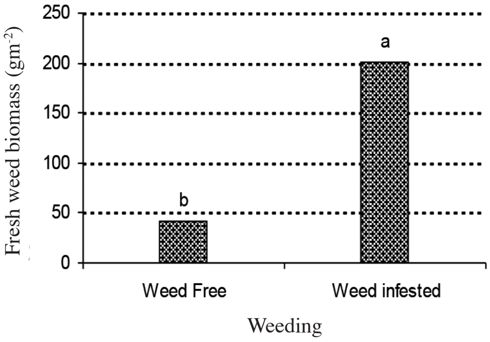

FIGURE 3. Mean fresh weed biomass in weed free and weed infested plots

Mean values of the treatments are given in Figure 4. These values show that in NPK (134 g m^{-2}) and N (133 g m^{-2}) treated plots maximum fresh weed biomass is observed followed by NP (126.3 g m^{-2}) and minimum fresh weed biomass (99.5 gm^{-2}) is seen in the control group and K (133.1 g m^{-2}) treated plots. In other treatments values are intermediate and similar on statistical basis. The fresh weed biomass in nitrogen treated plots is higher than other treatments especially control plots when we look at the overall means of the treatments. The instant results suggested that fertilizer application benefited the mixed population of weeds and hence make the weed more competitive with the maize crop. Rasheed et al. (2004) reported that the soils around the study area are 100% deficient in nitrogen and up to 90% in phosphorus. Therefore fertilizers are applied at higher rates. But these should be applied in the form of band or placement methods so that the crops benefit better in comparison with weeds. The yields are significantly affected by the slow release of NPK which in turn affects the yield, shoot length and nitrogen portion in grass as reported by Maharijaya and Nasrullah (2008).

There is a significant interaction between WF/WI and fertilizers (Table 1). The data showed that the minimum fresh weed biomass (38.3 g m^{-2}) in control under WF condition. On the other hand maximum fresh weed biomass (223.0 g m^{-2}) was in NPK treated plots under WI condition. We can conclude that N, P and K combinations have a

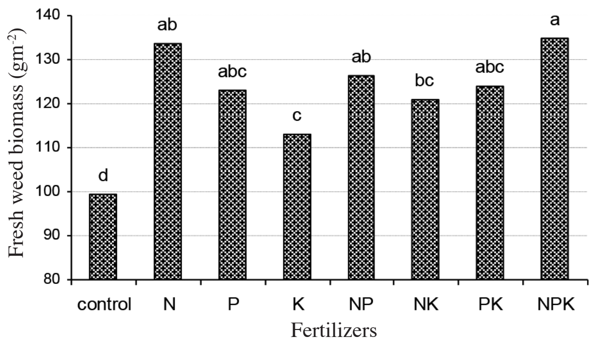

FIGURE 4. Mean fresh weed biomass in fertilizer treated plots

more favourable effect on weeds as compared to their applications singly. All vegetative growth parameter show enhancement due to nitrogen resulting in a shoot biomass which is higher together with taller plants, with more leaf number and tillers (Akamine et al. 2007). Maize is seriously infested with different grassy and broadleaf weeds and weed control is inevitable at all the farms in the area therefore judicious use of fertilizer and weed management can make the farming more profitable. Mechanical and/or manual weeding is practiced in maize but the situations become more complicated when monsoon rains started. Thus early weed control or application of herbicide is a fair choice for the farmers to avoid yield losses.

DRY WEED BIOMASS (DWB-g m^{-2})

DWB in WF plots was lower than the WI plots (Figure 5) when analyzed statistically. Higher values of dry weed biomass (49 g m^{-2}) were observed in plots infested with weeds as against 17 gm^{-2} in plots which were free of weeds. The maize grain yield was directly affected by the weed dry biomass. In view of this the weed control method should focus on the problem how to suppress the growth of weeds rather than weed density. As weeding was done up to first six weeks after sowing, therefore the dry biomass recorded in the weed free plots was acceptable as this biomass cannot affect the yield significantly.

Figure 6 shows the means of fertilizer treatments. It shows that dry weed biomass values are maximum in NP and

FIGURE 5. Mean dry weed biomass in weed free and weed infested plots

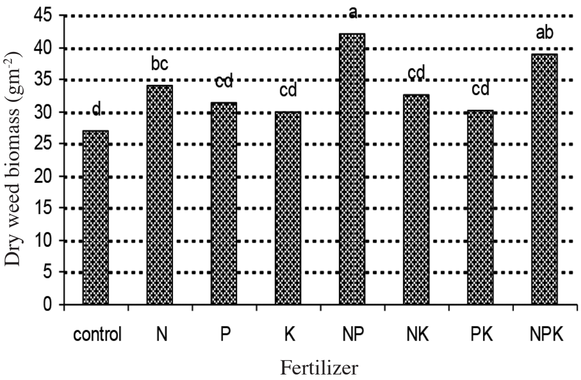

FIGURE 6. Mean dry weed biomass in fertilizer treated plots

NPK N treated plots follow these, with 42, 38 and 34 g m^{-2} values, respectively. In the controls a minimum dry weed biomass is observed depending on the treated plots as 27 g m^{-2}, 29 gm^{-2} (K) and 30.1 g m^{-2} (PK). In other treatments the values were statistically comparable with each other. A comparatively higher dry weed biomass is seen in nitrogen treated plots than other treatments when we look at the overall means of the treatments. This could be attributed to the fact that growth and development of weeds is accelerated by nitrogen. This is fully supported by our findings that the growth of weed taxa in our experimental plots is stimulated by the application of fertilizers, especially nitrogen. The seed production potential of weeds will increase due to vigorous vegetative growth following fertilizer applications. As such, the problem of weeds will increase due to fertilizer applications and this needs to be addressed properly. Akamine et al. (2007) have clearly shown that there is an increase in the vegetative growth following application of N alone or in combination with P or K.

A non-significant (p<0.05) correlation is observed related to the interaction between WF/WI and fertilizer (Table 1). A maximum DWB (62.7 gm^{-2}) is recorded in NP treated plots under WI (Table 1) and a minimum DWB (10.7 gm^{-2}) in control under WF conditions. Many rodents are seen to get shelter in the plots infested with weeds, which proved the worst pests for maize plants and of cobs. Lodging of several maize plants have been observed in the weed infested plots as rodents had holes in these plots. Although growth and light transmittance were similar to the control in NK treatment, maize also suffered from P deficiency as reported by Yin et al. (2006). However, in the plots getting NP treatment growth reduction of crop was not so severe as in NK and PK. A combined application of N, P and K nutrients resulted in a higher maize yield. The reason for this is that vegetative growth of the plants is stimulated by nitrogen, this probably also leads to a luxurious vegetative growth of weeds.

500 KERNELS WEIGHT (g)

The total yield of maize is directly affected by the weight of Kernels. A statistical difference (p<0.05) was recorded in the 500 kernels weight (g) among the WF and WI plots (Figure 7) as per the means obtained. The 500 kernels weight of maize was only 12.2 g under WI conditions as compared with 144 g in the WF plots. The unusual kernel weights in WI plots are because there were no harvestable cobs here. This was the reason that the weight of 500 kernels was much less when an average is calculated among the treatments. All the weeds recorded in the experimental field are strong competitors and thus resulted in the total failure of the crop. In the plots subjected to hoeing a maximum 500 grain weight was recorded. The reason for this is an establishment of a better crop stand due to hoeing leading to maximum grain biomass as reported by EI-Bially (1995) and Gokmen et al. (2001).

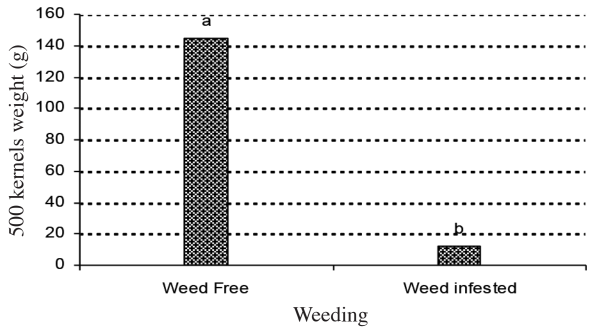

FIGURE 7. Mean 500 kernels weight in weed free and weed infested plots

In Figure 8 the means of the fertilizer treatments are shown. The maximum 500 kernels weight is found in K (91.7 g) and N (90.3 g) treated plots followed by PK (78.3 g). The minimum 500 kernels weight is found in the control (64.8 g) and NP (74.3 g) followed by P (75.1 g). No statistical difference was observed. Perusal of the data depicts that all the macro-nutrients have positive effect on the 500 kernels weight. Thus both weeds and maize benefited from the macro-nutrient applications. A timely application of fertilizers and weed management appear to us as important as the removal of weeds or application of fertilizers.

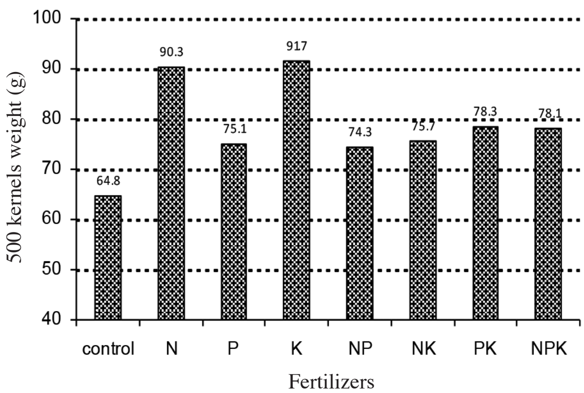

FIGURE 8. Mean 500 kernel weight in fertilizer treated plots

Interaction of WF/WI and fertilizers was non-significant (Table 2). Under WF conditions 500 kernels weight (156.6 g) is heavier in PK, although zero values were obtained in several treatments due to the absence of harvestable cobs.

GRAIN YIELD (kg ha^{-1})

The grain yield of maize is statistically different in WF and WI plots (Figure 9). The maize grain yield (50.9 kg ha^{-1}) is lower according to the means of WF/WI in the plots under WI conditions. The maize grain yield (2821.7 kg ha^{-1}) is higher in the plots under WF conditions. There were only few plants that produced harvestable cobs in the weed infested plots. The results stressed the findings that WI decreases the yield of crops to an extent where production cost crosses the acceptable limits. Our observations showed that when resource availability and crop yield are considered, limited availability of soil resources contributes to low grain yield as reported by Sobkowicz and Tendziagolska (2005).

In Figure 10 results related to the means of fertilizer treatment are given. In NP (1974.8 kg ha^{-1}) and NPK (1951.3 kg ha^{-1}) treated plots grain yield is maximum followed by N (1831.8 kg ha^{-1}), but grain yield (447.1 kg ha^{-1}) was minimum in control and potassium treated plots (913.3 kg ha^{-1}). Intermediate values were recorded in other treatments. These were statistically at par with each other. Overall findings stress that nitrogen application alone may prove effective towards increasing the yield, but a maximum grain yield will result when applied in combination with phosphorus. Our results confirm the fact that available resource sharing is possible with the occurrence of weeds, as such both weed control and fertilizer application are equally important. The interaction between weeding and fertilizers too is important (Table 2). The grain yield in WF situations is maximum (3949.7 kg ha^{-1}) in NP treated plots, but a zero grain yield is observed in some treatments even under WI conditions. Therefore for maize production both weed control and fertilizer applications are important. We see crop failures in summer maize in many cases because they are facing a serious problem of weed infestation; farmers ignore weeds and give priority to fertilizer applications. These weeds are harvested by farmers at maturity together with the crop since their thinking is multipurpose use of the same filed, where weeds will serve his cattle as fodder and crop will be used by him for his own purposes. There is a dire need for training of farmers for harvesting of weeds at the proper time in order to overcome the crop losses. We see that both number of grains m^{-2} and the weight of 1000 grains is reduced by P deficiency as reported by Plenet et al. (2000). The impact of fertilizers is greater on the soil P pools than on the plant P uptake (Krey et al. 2013).

TABLE 2. Effect of different combinations of NPK on 500 kernels weight and grain yield of maize

Treatment	500 kernels weight (g)		Grain yield of maize (Kg ha^{-1})	
	Weed free	Weed infested	Weed free	Weed infested
Control	129.7	0.00	894.3 f	0.0 g
N	144.00	36.67	3523.3 ab	140.3 g
P	119.00	31.33	2940.3 cd	115.0 g
K	153.33	30.00	1674.7 e	152.0 g
N plus P	148.7	0.00	3949.7 a	0.00 g
N plus K	151.33	0.00	3132.0 bc	0.00 g
P plus K	156.67	0.00	2556.7 d	0.00 g
N plus P plus K	156.33	0.00	3902.7 a	0.00 g

DAS=Days after sowing; LSD value for grain yield = 435

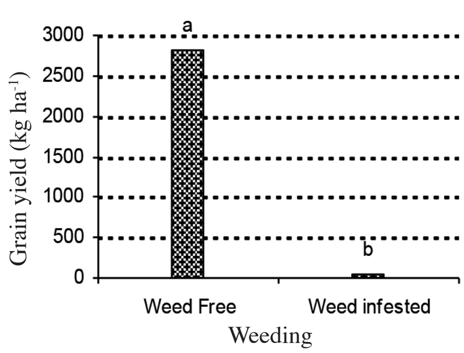

FIGURE 9. Mean grain yield in weed free and weed infested plots

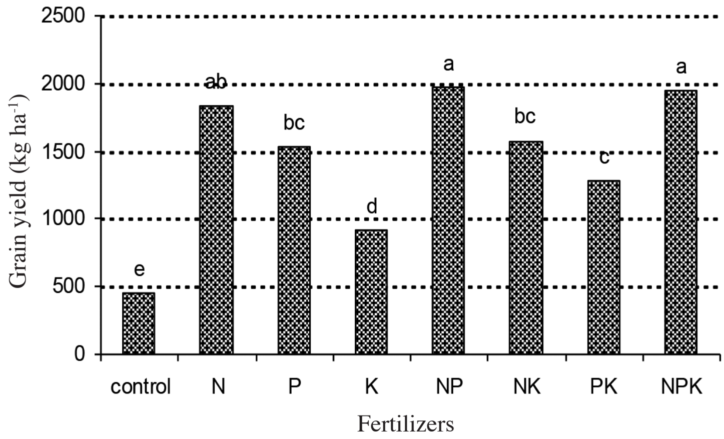

FIGURE 10. Mean grain yield in fertilizer treated plot

CONCLUSION

Maize is a summer crop as such, manual weeding is very difficult and/or impossible for the farmer. In particular those having large areas should apply herbicides, but in an integrated weed management approach.

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