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Influence of Integrated Nutrients on Growth, Yield and Quality of Maize (*Zea mays* L.)

Azhar Ghaffari, Asghar Ali, Muhammad Tahir, Muhammad Waseem*, M. Ayub, Asif Iqbal, Atta Ullah Mohsin

Department of Agronomy, University of Agriculture, Faisalabad, 38040, Pakistan; *Corresponding Author.
Email: mianwaseem_1028@yahoo.com

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ABSTRACT

A field experiment was conducted to evaluate the integrated nutrients effect on growth, yield and quality of maize (*Zea mays L.*) *during spring*, 2009, *at the Agronomic Research Area, University of Agriculture, Faisalabad. The experiment was laid out in Randomized Complete Block Design* (*RCBD*) *having three replications with following treatments*: T_1 (*control*), T_2(*recommended NPK @* 200-120-125 *kg* ha^{-1}), T_3 [*single spray of multi-nutrient* (*a solution mixture of micronutrients i.e*; *Zn* = 2%, *Fe* = 1%, *B* = 1%, *Mn* = 1%, *Cu* = 0.2% *and macronutrients N* = 1%, K_2O = 2%, *S* = 2%) @ 1.25*L*ha^{-1}], T_4 (*recommended NPK* @ 200-120-125 *kg* ha^{-1} + *single spray of multi-nutrient @ 1.25L* ha^{-1}), T_5 (*recommended NPK* @ 200-120-125 *kg* ha^{-1} + *two spray of multi-nutrient* @1.25*L*ha^{-1}) *and* T_6 (*recommended NPK* @ 200-120-125 *kg* ha^{-1}+ *three spray of multi-nutrient* @ 1.25*L*ha^{-1}).*The recommended dose of NPK in addition with single spray of Multi-nutrients substationally improved all growth parameters, ear characteristics and also enhanced macronutrients use efficiency up to* 11.5% *which induced significant increase in grain yield as compared to control and also in the treatment where recommended dose of NPK was applied alone. The quality parameter of maize* (*oil contents*) *significantly improved by foliar application of multi-nutrients solution but recommended dose of fertilizer in addition to single spray of Multi-nutrients was economical.*

Keywords: *Multi-Nutrients, Foliarapplication, Nutrients Use Efficiency, Oil Content*

1. Introduction

Intensive crop rotation and imbalance fertilizer use have resulted in a wide range of nutrients deficiency in fields. For intensive cropping systems, the current recommended fertilizers rates need revision upwards with in balance ratio of vital micronutrients specific to crop to enhance stagnant yields [1]. By supplying plants with micronutrients, either through soil application, foliar spray, or seed treatment improved yield, quality and macronutrient use efficiency was improved up to 50% [2].

Developing countries contribute a major share in the world cultivated land of maize which is nearly 67% but their share in production is only about 46%, where approximately 60% of the world maize is produced by USA and China collectively [3]. There are many factors responsible for lower grain yield in these countries including Pakistan such as improper selection of genotype or hybrid, less optimal plant population in the field and absence of standard crop husbandry for hybrids of varying maturity groups. Among these, fertilizer management plays an important role for obtaining satisfactory yield. In order to increase crop productivity nutrient management may be achieved by the involvement of organic sources, bio-fertilizers and micro-nutrients [4]. Micronutrient deficiency can greatly disturb plant yield, quality and the health of domestic animals and humans [5]. Full exploitation of the genetic potential requires intensive fertilizer application, but it increases the cost of the products. Also, about 50% of applied N and 70% of applied potassium to the soil remain unavailable to a crop due to a combination of leaching, fixation, and volatilization. However, the waste of the nutrients can be reduced by foliar applications of dilute solutions [6]. Witt *et al.*, (2006) [7] stated that preliminary results of on-farm trials with maize clearly indicate opportunities to increase yield and profitability, if crop and integrated nutrient management are fine-tuned to site-specific conditions. Rasheed *et al.*, (2004) [8] and Vilela *et al.*, (1995) [9] also observed significant improvement in maize grain yield in response to N and S application.

The integrated nutrient management has been paid little attention in agriculture areas of developing world [10]. Available literature indicates that in Pakistan, deficiencies of micronutrients have emerged in most of the farmer's fields due to continuous use of conventional NPK fertilizers which lack many of the vital micronutrients and the trend may deplete the natural nutrient supply in intensively cultivated areas. So, very little work has been done on commercial foliar fertilizers under agro-climatic conditions of Pakistan. There- fore, the present study was executed to evaluate the integrated nutrients use effect on growth, yield and quality of maize.

2. Materials and Methods

A field study was conducted to evaluate the Influence of integrated nutrients on growth, yield and quality of maize (*Zea mays* L.) at the Agronomic Research Area, University of Agriculture, Faisalabad. The experiment was laid out in Randomized Complete Block Design (RCBD) having three replications and following treatment T_1 (control), T_2 (recommended NPK @ 200-120-125 kg ha^{-1}), T_3 [single spray of multi-nutrient (a solution mixture of micronutrients *i.e*; Zn = 2%, Fe = 1%, B = 1%, Mn = 1%, Cu = 0.2% and macronutrients N = 1%, K_2O = 2%, S = 2%) @ 1.25Lha^{-1}], T_4(recommended NPK @ 200- 120-125 kg ha^{-1} + single spray of multi-nutrient @ 1.25L ha^{-1}), T_5 (recommended NPK @ 200-120-125 kg ha^{-1} + two spray of multi-nutrient @ 1.25L ha^{-1}) and T_6 (recommended NPK @ 200-120-125 kg ha^{-1} + three spray of multi-nutrient @ 1.25L ha^{-1}). Maize hybrid (Pioneer-32B33) was used in this study. In each treatment 5 rows of maize were sown. The rows were 70 cm apart with plant to plant distance of 20 cm. First foliar application of Multi-nutrients was sprayed at 4-5 leaves stage where second and third foliar sprays were applied after one week interval. The observations plant height at maturity, number of grain rows per cob, number of grains per cob, 100-grains weight, grain yield, biological yield, fertilizer use efficiency and harvest index were recorded. The collected data was analyzed statistically by using Fisher's analysis of variance technique and individual treatment means were separated by using least significant difference (LSD) test at 5 percent probability level [11].

Oil contents were determined by Soxhlet Fat Extraction method described by Low, 1990 [12]. Soil samples were taken before sowing of crop to depth of 30 cm for physiochemical analysis. The soil sample analytic report is presented in **Table 1** which showed hunger of soil to specific nutrients in which all nutrients were below the critical range to some extent where K was sufficient in soil as described by Sims and Johnson, 1991 [13] critical range of nutrients in soil. The extraction of available p was made using DTPA method.

3. Results and Discussion

3.1. Plant Height

Plant height reflects the vegetative growth behavior of crop plants to applied inputs. Data pertaining to plant height were collected and subjected to statistical analysis is presented in table-II showed significant effects of multi-nutrients solution spray on height of maize plants. The comparison of treatment means revealed that maximum plant height (176.09 cm) was achieved when single spray of multi-nutrients was applied along with recommended basal dose of NPK (T_4) to maize plants. The treatment (T_4) was significantly differ with T_1 (control), T_2 (recommended dose of fertilizer @ 200-120-125 kg NPK ha^{-1}) and T_3 (single spray of Multi-nutrients @ 1.25 L ha^{-1}), where it was statistically at par with T_6 (recommended dose of fertilizer + 3 sprays of Multi-nutrients), T_5 (recommended dose of fertilizer + 2 sprays of Multi-nutrients).

Plant height increase in response to multi-nutrients in studies conducted on maize [14] and wheat [15] which affirmed that further increase in rate of multi-nutrients application did not show any increment which may be possibly due to the presence of antagonistic affects, negative interactions and toxicity of some nutrients to plant as a complex phenomena that occurred when nutrients were used in combination [16].

3.1.1. Number of Grain Rows per Cob

Number of grain rows per cob which revealed a significant difference among treatments as showed in table II. The comparison of treatment's means exposed that foliar application of multi-nutrients is very effective in terms of grain rows per cob as showing great variation from 17.06 to 6.13. The highest value attained in T_4 (recommended

Table 1. Pre sowing physio-chemical analysis of soil.

Textural class	Saturation (%)	pH	EC_e	O.M (%)	N (%)	P ppm	K ppm	Zn ppm	Fe ppm	Cu ppm	Mn ppm	B ppm	S ppm
Loam	33	7.65	2.1	0.58	0.04	6.64	183.3	0.52	3.8	0.15	1.3	0.92	Nil

dose of fertilizer + 1 spray of Multi-nu- trients) where lowest number of grain rows observed in control (T_1). The T_4 (recommended dose of fertilizer + 1 spray of Multi-nutrients) treatment is statistically at par with T_2 (recommended dose of fertilizer @ 200-120-125 kg NPK ha^{-1}) and T_5 (recommended dose of fertilizer + 2 sprays of Multi-nutrients) where both are at par with T_6 (recommended dose of fertilizer + 3 sprays of Multi-nu- trients). Since grain rows emergence and development depends on environmental factors like vigor, nutrient provision in proper proportions that induce it, therefore different sources of fertilizers and their combinations create statistically significant differences in the treatments. The number of grain rows per cob varied to applied nutrients as these outcomes substantiate by the findings of Bakry *et al.* (2009) [17] who reported that different micronutrients and their combination was testified on maize crop which proved beneficial and salubrious in enhancing all physiological and yield parameters of maize crop and also gave a good response in term of number of grain rows per cob. On the basis of experiment conducted by Kruczek, 2005 [18] by applying different levels of multi-component fertilizer on maize crop, it is cleared that multi-nutrients fertilizers have a significant affect on number of grain rows per cob. The possibly reason for lower number of grain rows per cob in T_5 (recommended dose of fertilizer + 2 sprays of Multi-nutrients) and T_6 (recommended dose of fertilizer + 3 sprays of Multi-nutrients) treatments may be attributed to the antagonistic affect of micronutrients and their negative interaction as increase in B concentration beyond the certain limit have a negative impact on uptake of Zn [19], [20]; and [21].

3.1.2. Number of Grains per Cob

The results obtained from the data collected showed in table II suggested significant response of spring maize plants in terms of number of grains per cob to integrated nutrient management approaches. The contrast study of means showed a great variation in grains per cob which confirmed the micronutrients affect on quantity of grains. The frequency of multi-nutrients application gave different responses as highest number of grains (450.67) was observed in T_4 treatment where basal dose of NPK @ 200-120-125 kg ha^{-1} supplied with single spray of multi-nutrients solution @ 1.25 L ha^{-1}. The second highest and statistically significant number of grains (401.93) was achieved in treatment T_2 where recommended rate of fertilizer @ 200-120-125 kg NPK ha^{-1} was applied however, T_5 (recommended dose of fertilizer + 2 sprays of Multi-nutrients) and T_6 (recommended dose of fertilizer + 3 sprays of Multi-nutrients) are statistically at par with T_2 treatment. The lowest number of grains (84.27) was attained in T_1 (control) treatment which is statistically at pat with T_3 (106.60) where only single spray of Multi-nutrients @ 1.25 L ha^{-1} was applied without any basal dose of NPK. The increment in number of grains per cob might be due to the presence of magnesium in Multi-nutrients solution as grains number are direct index of pollen viability and where magnesium is proved to be increases fruit set and pollen viability, and significant affect on pollen formation [22] and [23].

3.1.3. 100-Grain Weight (g)

Mean grain weight is an important yield contributing factor, which plays a decisive role in showing the potential of a variety. The data regarding the 100-grain are presented in table II. The results confirmed the significant influence of micronutrients on grain weight. A comparative study of means showed considerable variations in treatment means varying from 33.58 to 26.70 g weight for 100-grain. The maximum 100-grain weight obtained when maize plants received basal dose of conventional fertilizer with single spray of multi-nutrients solution (T_4). Treatment means where recommended dose of fertilizer + 2 sprays of Multi-nutrients (T_5), recommended basal dose of NPK @ 200-120-125 kg ha^{-1} (T_2) and recommended dose of fertilizer + 3 sprays of Multi- (T_6) was applied appeared statistically similar but these differ significantly from T_1 (control) and T_3 (single spray of multi-nutrients @ 1.25 L ha^{-1}). The least weight for 100-grain (26.70 g) was recorded in T_1 (control) which is statistically same with output of treatment T_3 (27.22 g) where multi-nutrients was sprayed alone. The weight of grains depend on flabbiness of grains and transport of assimilates to the seed [23].The potassium and magnesium exerted a positive influence on the weight of grains, since both elements participate in the transportation of carbohydrates to the sink organs [24]. The 100-grain weight is lower in NPK treatment as compare to T_4 (recommended dose of fertilizer + 1 spray of Multi-nutrients) treatment.

3.1.4. Grain Yield (t ha-1)

Data regarding grain yield in table II showed significant enhancement in yield of maize plants. The comparison of means for the grain yield (t ha^{-1}) of maize plants at different nutrients management treatments is given in table 4.10 which showed a minimum value of 0.723 t ha^{-1} for control maize plots and maximum value of 5.780 t ha^{-1} for the T_4 (recommended dose of fertilizer + 1 spray of Multi-nutrients) treatment. Maximum grain yield was followed by T_2 (recommended dose of fertilizer @200-120-125 kg NPK ha^{-1}), T_5 (recommended dose of fertilizer + 2 sprays of Multi-nutrients) and T_6 (recommended dose of fertilizer + 2 sprays of Multi-nutrients) as 4.13, 3.81 and 3.58 t ha^{-1} respectively, where these treatments were statistically at par with each other. The least grain yield was recorded in T_1 (0.72 t ha^{-1}) and T_3 (1.24 t ha^{-1}) where single spray of Multi-nutrients@ 1.25 L ha^{-1} was applied, both were statistically same.

This increase may be mainly due to the additional availability of nutrients as foliar sprays where T_5 and T_6 treatments results were not statistically significant as compare to T_4 treatment's out come. Its might be the multi-nutrients composition of solution which enabled maize plants of treatment T_4 to attained maximum grain yield and yield attributes while decline trend in other multi-nutrients treatments might be due to the negative interaction of micronutrients as their concentrations increases per treatment [25]. Lisuma *et al.* (2008) [26]who reported that the use of micronutrients contributed to increase yields when applied in combination of macronutrients as compared to conventional fertilization which lack of micronutrients. Similar trend was observed by Singh *et al.*, (2009) [27] in wheat crop who claimed that 100% NP plus single spray of micronutrients gave best results in comparison to other treatments. The maximum yield achieved when best site specific nutrient management approaches were used, in a study conducted by Bakry *et al.* (2009) [17] which revealed that micronutrients played a critical role in achieving higher yield in conjugation with manures. A decrease trend of grain yield with increasing rate of multi-nutrients solution was also observed by (Lana *et al.*, 2007) [28] who stated that up to a certain level yield boosts with rising rate of multi-nutrients but further increase in rate of nutrients did not respond linearly and might be it drastically reduces the yield.

3.1.5. Biological Yield (t ha^{-1})

Data pertaining to biological yield as affected by foliar applied different micro- and macro- nutrients is presented in table II. Biological yield differed significantly among various levels of nutrients. The results regarding analysis of variance of post treated data revealed that biological yield of maize plants varied from maximum 15.73 t ha^{-1} attained in T_4 (recommended dose of fertilizer + 1 spray of Multi-nutrients) to lowest value 2.707 t ha^{-1} observed in control (T_1) treatment. Where as the maximum value for biological yield was statistically similar with 13.750 t ha^{-1} and 12.460 t ha^{-1}, these values gave by treatment T_2 (recommended dose of fertilizer @200-120-125 kg NPK ha^{-1}) and T_5 (recommended dose of fertilizer + 2 sprays of Multi-nutrients) treated maize plants respectively. In T_6 (recommended dose of fertilizer + 3 sprays of Multi-nutrients) treatment biological yield of maize plants was 11.997 t ha^{-1} which statistically at par with outcome of T_2 and T_5 treatments. The treatment T_3 where single spray of multi-nutrients@ 1.25 L ha^{-1} was sprayed without any basal dose of NPK showed 6.180 t ha^{-1} biological yield, which significantly differed from control (2.707 t ha^{-1}) treatment.

The biological yield increment might be due to manganese application which significantly improve uptake of Mg, Zn and Mn in corn. So, micronutrients may be attributed enhanced photosynthesis, early growth and nitrogen fixation as Zn and other vital nutrients was present in multi-nutrients solution. These results are in conformity with findings of Ali *et al.* (2008) [28] and Welch (2003) [5] who stated that application of micronutrients combinations gave highest biological yield as grain yield was also influenced which might be attributed to the additional availability of nutrients. Similar pattern in response to mix fertilization of micronutrients in maize was also given by Lana *et al*., (2007)[29].

3.1.6. Harvest Index (%)

The physiological ability of a hybrid to convert total dry matter in to grain yield is determined by its Harvest Index (HI). The **Table 2** pertain the data concerning harvest index (HI) of maize plants as affected by nutrient management practices.

The analyzed data revealed that significant affect on harvest index was observed among fertilizer treatments. The comparison of mean study showed variation in harvest index from 36.638 to 24.297. The maximum value for harvest index was observed in T_4 where recommended dose of basal fertilizer along with 1 spray of Multi-nutrients was applied. The treatments T_2 (recommended dose of fertilizer@200-120-125 kg NPK ha^{-1}), T_5 (recommended dose of fertilizer + 2 sprays of Multi-nutrients) and T_6 (recommended dose of fertilizer + 3 sprays of Multi-nutrients) was statistically similar for harvest index values 30.447, 30.283 and 29.260 respectively. The least harvest index (24.297) was recorded in control treatment which was statistically at par with outcome of single spray of Multi-nutrients@ 1.25 L ha^{-1} treated maize plants in T_3 treatment (25.217).

These results are in agreement with the findings of the Sajedi *et al.* (2009) [30] who investigated the micronutrients impact on salinity stressed maize plants under water deficit conditions. The outcomes of this study proved that harvest index was significantly affected by micronutrients application when maize plants were receiving normal irrigation and no selenium was applied.

3.1.7. Fertilizer Use Efficiency (kg-1)

Fertilizer Use Efficiency (FUE) is also called nutrient to grain ratio. The major macronutrients (N, P and K) use efficiency was significantly influenced by micronutrients foliar sprayed as showed in table II. The treatments showed that highest FUE was observed in T_4 where

Table 2. Influence of integrated nutrient management practices on maize yield, yield component, FUE and oil content.

Treatments	Plant height (cm)	No. of grain rows per cob	No. of grains per cob	100-grain weight (g)	Grain yield t ha^{-1}	Biological yield t ha^{-1}	Harvest index (%)	Fertilizer use efficiency	Oil contents (%)
T_1) Control	102.5c	6.1d	84.2d	26.7c	0.72c	2.7d	24.29c	0	3.3c
T_2) recommended dose of fertilizer (200-120-125 kg NPK ha^{-1})	154.9b	15.6ab	401.9b	30.5b	4.13b	13.75ab	30.44b	7.8b	4.6b
T_3) Single spray of Multnutrients (1.2 L ha^{-1})	114.1c	9.1c	106.6d	27.2c	1.55c	6.18c	25.21c	2.02d	3.6c
T_4) T_2 + 1 spray of Multi-nutrients	176.9a	17.0a	450.67a	33.5a	5.78a	15.73a	36.63a	11.53a	4.96ab
T_5)T_2 + 2 sprays of Multi-nutrients	168.5ab	15.4ab	349.3c	30.7b	3.8b	12.46ab	30.28b	7.08c	5.2a
T_6)T_2 + 3 sprays of Multi-nutrients	168.2ab	14.53b	308.9c	29.4b	3.58b	11.9b	29.87b	6.57c	5.27a
LSD Value	15.05	2.47	42.10	1.77	1.30	3.47	3.11	3.39	0.37

Any two means not sharing same letter differ significantly at 5% level of probability.

multi-nutrients solution was sprayed once @ 1.25 L ha^{-1} along with basal dose of NPK (200-125-120 kg NPK ha^{-1}) which was 11.53%. In rest of treatments T_5 and T_6 where multi-nutrients was sprayed twice and thrice respectively along with recommended dose of NPK, appeared to be statistically similar with T_2 treatment where recommended dose of fertilizer@200-120-125 kg NPK ha^{-1} was applied. The lowest efficiency was recorded in T_3 (2.027) where multi-nutrients solution was sprayed once without any basal dose of fertilizers. These results are in harmony with Malkouti *et al*. (2008) [2] who reported that macronutrient use efficiency significantly improved. So, it strongly recommended that optimum level of microelements should be used rather than critical level in crops. Micronutrients application not only replenish the macronutrient concentration in grains they also enhance the efficiency of micronutrients in plants as studied by Orsozo *et al.* (2009) [31] in maize which proved their catalyst role in up taking of primary nutrients as well as other nutrients. Parallel trends were noted by (He *et al.*, 2009) [32].

3.1.8. Oil Contents (%)

Data concerning oil contents were subjected to statistical analysis and is represented in Table II as analysis of variance. The results of analyzed data showed significant affect of multi-nutrients application as compared to control. The comparative view of means revealed that crude oil content in grains was statistically similar among multi-nutrients applied treatments as T_4, T_5 and T_6 where multi-nutrients was sprayed once, twice and thrice respectively @ 1.25 L ha^{-1} along with recommended rate of fertilizer @ 200-120-125 kg of NPK ha^{-1}. The maximum value for oil contents was recorded in T_6 (5.27%) followed by T_5 (5.20%) and T_4 (4.96%) where as treatment T_4 was statistically at par with result of T_2 (4.60%) treatment which received recommended rate of fertilizer @ 200-120-125 kg of NPK ha^{-1} alone. The least value for crude oil content in grains was determined in control maize plants (3.33%) where this findings was same from statistics point of view with T_3 (3.63%) treatment. Crude oil contents of grains increases due to the disulphide bond formation between polypeptide chains which increases as sulfur concentrations increases. Sulfur is responsible for oil content increment as it is required in synthesis of co-enzyme A which involved in oxidation and synthesis of fatty acids. These results are in conformity with findings of (Rasheed *et al.*, 2004) [8] and (Vilela *et al.*, 1995) [9] who found that sulfur induced higher oil contents in maize grains.

3.2. Economic Analysis

The successful adoption of integrated nutrient management practice is finally determined the net financial gain (**Table 3**). The best nutrient management practice was T_4 where one spray of multi-nutrients was applied in conjugation with recommended dose of NPK attaining 41,170 Rs. net field benefits. The rest of treatment's net field benefits were to low to recommend for farmers.

4. Conclusion

Based on findings of study, it can be recommended that single spray of Multi-nutrients along with recommended

Table 3. Net field benefits (NFB) as influenced by integrated nutrient management practices.

Treatments	Gross income	Gross expenditure	NFB	BCR Increases or Decreases over control (%)
		(Rs. ha^{-1})		
T_1) Control	9,029	14,675	-	-
T_2) Recommended dose of fertilizer (200-120-125 kg NPK ha^{-1})	56,742	36,815	19,927	0.54
T_3) Single spray of Multi-nutrients(1.25 L ha^{-1})	21404	16,265	5,139	0.31
T_4) T_2 + 1 spray of Multi-nutrients	79,475	38,305	41,170	1.07
T_5) T_2 + 2 sprays of Multi-nutrients	52,387	39,795	12,592	0.31
T_6) T_2 + 3 sprays of Multi-nutrients	49,270	41,285	7,985	0.19

dose of NPK is feasible for enhancing yield, quality and nutrients use efficiency of maize hybrid Poineer-32B33 economically under agro-climatic conditions of Faisalabad Pakistan.

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