ORIGINAL ARTICLE

ISSN (Print): 2517-9675
ISSN (Online): 2518-2625

INTEGRATED USE OF MACRO AND MICRONUTRIENTS FOR IMPROVING YIELD AND YIELD COMPONENTS OF COTTON (*GOSSYPIUM HIRSUTUM* L.) UNDER ALKALINE CALCAREOUS CONDITIONS

Liaqat Ali[1*] • Mueen ud Din[1] • Mushtaq Ali[1] • Zafar Yab Haider[2] • Abdul Ghafoor[3] • Masood Qadir Waqar[4]

AUTHOR'S AFFILIATION

[1]Directorate of Agriculture (F,T & AR), Vehari Zone Vehari, Punjab, Pakistan
[2]Director General Agriculture (Extension & AR), Punjab, Lahore
[3]Directorate of Agriculture (coordination), Lahore, Punjab, Pakistan
[4]Directorate of Agriculture (M & E), Lahore, Punjab, Pakistan
[*]Corresponding author's e-mail: drliaqatali131@gmail.com

Keywords:
Gossypium hirsutum, integrated use, macro and microelements, yield and yield components, Pakistan

ABSTRACT

Background Plant growth primarily depends on the application of synthetic fertilizers to correct natural deficiencies of plant nutrients in soil. However, crop response to fertilizer application may change significantly depending upon many plant and soil factors as well as concentration and application pattern of applied nutrients.

Methodology A field study was designed to evaluate the effect of applied macro and micronutrients on yield and yield contributing traits of cotton. The study was comprised of three treatments; T_1: Recommended NPK @ 340-114-92 kg ha^{-1}, T_2: NPK + Zn 7.5 kg ha^{-1} + B 7.5 kg ha^{-1} + Fe 5 kg ha^{-1}, T_3: NPK + Zn 7.5 kg ha^{-1} + B 7.5 kg ha^{-1} + Fe 5 kg ha^{-1} + Cu 2.5 kg ha^{-1}. The experiment was laid out in split plot design with three replications using two cotton varieties MNH-886 and FH-142.

Results The results of Kharif 2016 showed that the treatment T_3 proved as the most balanced fertilizer dose for higher seed cotton yield (2266 kg ha^{-1} for MNH-886 and 2159 kg ha^{-1} for FH-142) with higher number of bolls plant^{-1} (30.2 for MNH-886 and 26.6 for FH-142) and boll weight (3.19 g for MNH-886 and 2.92 g for FH-142) closely followed by the treatment T_2. Whereas, results of Kharif 2015 behaved differently and depicted that T_3 and T_2 showed the yield at par (1914, 1907 kg ha^{-1}) and boll weight 3.28 and 3.22 g as well as number of bolls plant^{-1} (26.2 and 24.4) against the minimum seed cotton yield of 1880 kg ha^{-1}, number of bolls plant $^{-1}$ (21.2) and boll weight (3.04 g) for MNH-886 in the plots where only NPK was applied. When compared the both varieties, MNH-886 performed better than FH-142 at all fertilizer levels.

Conclusion For sustainable and profitable cotton production, growers need to change traditional plant nutritional programs to an integrated nutrient management system consisting of macro and micronutrients. Moreover, the Bt cotton variety performed better than synthetic at all fertilizer levels.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is an integral component of national economy as Pakistan is the fourth largest producer, third largest exporter and fourth largest consumer of cotton in the world (Rehman et al. 2017.). The area under cotton cultivation has been increased extensively for the last 30 years, about 7.86 million acres during 2015-16 in the country. It contributes more than 55% to the total foreign exchange earnings, 10% gross domestic production while the seed cotton for oil and meal accounts for around 80% of the national production of oil seed (Anonymous 2016). However, the productivity of cotton in Pakistan is far low compared to many other cotton producing countries (Rehman et al. 2015). Among different factors, inadequate and imbalanced supply of plant nutrients is more important contributor to poor cotton growth and seed cotton yield in Pakistan. Many studies have demonstrated that optimal fertilization with nitrogen (N), phosphorus (P) and potassium (K) is an important

Cite As: Ali L, M Din, M Ali, ZY Haider, A Ghafoor, MQ Waqar (2017) Integrated use of macro and micronutrients for improving yield and yield components of cotton (*Gossypium hirsutum* L.) under alkaline calcareous conditions. *J. Environ. Agric.,* 2(1): 181-185.

consideration for harvesting higher cotton yield, but farmers usually make overuse of N fertilizer along with insufficient dose of P, K and micronutrients (Cuin et al. 2008; Shah et al. 2012; Khan et al. 2016). Soil tests carried out in Pakistan showed a general lack of N, a wider spread deficiency of P and micronutrients, particularly zinc (Zn), iron (Fe), boron (B), copper (Cu) and manganese (Mn) (Wahhab 1985; Ibrahim et al. 2007; Shah et al. 2012). Deficiency of N in cotton can reduce both vegetative and reproductive growth and induce premature senescence, leading to potential yield losses (Gerik et al. 1994). Phosphorus is of great importance for cotton and other crops due to its inherent role in the synthesis of ribonucleic acid (RNA) and in the mechanism of energy transfer as it is main constituent of adenosine triphosphate (ATP) (Nachimuthu et al. 2009). Several factors including soil type, fertilizer type, fertilization rate, application time and method may affect cotton response to P fertilization. The critical level of P is a function of actual concentration of the labile pool that in turn determines the available P at a given time during the growth of cotton (Crozier et al. 2004). Potassium is involved in water relations, enzyme activation, metabolites translocation and many other functions in plants. Pettigrew (2003) reported that K fertilization increased cotton yield by 9% in 2 years of a 3 years study. Abd El-Mohsen and Ahmed (2015) investigated that the application of recommended dose of mineral N and K fertilizer (70 kg N fed^{-1} and 24 kg K_2O fed^{-1}) gave the highest values of plant height, number of open bolls plant^{-1}, boll weight, seed index, lint percentage, seed cotton yield plant^{-1} and seed cotton yield fed^{-1}. Ali et al. (2016a) concluded that to maintain profitable production, cotton producers may need to change traditional fertilization program to an integrated system consisting of soil and foliar applied nutrients. Ali et al (2016b) evaluated that recommended dose of NPK through soil application proved superior to improve wheat yield and yield contributing parameters as compared to 50% recommended NPK with foliar spray of NPK.

Deficiency of more than one nutrient is frequent in alkaline calcareous soils throughout the world and also in Pakistan (Imtiaz et al. 2010). Fageria et al. (2002) reported that with the introduction of high yielding varieties, high cropping intensity, calcareous nature and alkaline reaction soils, imbalanced application of plant nutrients and low or no use of organic manures caused widespread deficiencies of micronutrients. Plant nutrition through integrated use of mineral and organic sources is an integral component of foliar growth, root development, cell division, enzyme activation, flowering, and seed and fruit formation, and deficiency of any essential nutrient significantly hampers the plant growth and subsequently yield (Brady 1984, Cioroi and Florea 2003; Mousavi 2011).

Among the macronutrients, excessive and indiscriminate use of phosphatic fertilizers can affect the chemical or physiological interactions in soil-plant systems. These interactions, known as P induced micronutrients disorders, which reduce the solubility of micronutrients (Zn, B, Cu, Fe and Mn), leading toward their non-availability to plants (Timmer and Teng 1990). This P induced micronutrients deficiency has been reported in various soils and crops (Wang et al. 1990; Ajouri et al. 2004). Boron deficiency or excess may affect the solubility and availability of macro and micro-nutrients in soil (Tariq and Mott 2007; Ahmed et al. 2008). Rational use of macronutrients (NPK) is necessary for maintaining soil fertility as well as ensuring the solubility and availability of micronutrients. Among micronutrients, Zn, B, Fe and Cu fertilizers hold significant importance in not only sustaining but also enhancing the yield of cotton. Ahmed et al. (2011) conducted an experiment on calcareous soils under irrigated conditions by using six levels of B fertilizer (i.e. 0.0, 1.0, 1.5, 2.0, 2.5 and 3.0 kg B ha^{-1}). They concluded that application of B fertilizer significantly enhanced biological yield of cotton. Maximum dry matter yield was achieved by the addition of 3.0 kg B ha^{-1}. They also found that the addition of various levels of B caused substantial increase in the uptake of N, P, K, Cu, Fe, Zn and B, while lowering down the uptake of calcium (Ca) magnesium (Mg) and manganese (Mn) in different parts of the cotton plant. The enhanced assimilation of macronutrients resulted in greater production of biological yield as well as better growth and development of cotton plant. Ravikiran et al. (2012) conducted an experiment to study the effect of macro and micronutrients on growth and yield of Bt cotton under irrigated conditions. The results revealed that application NPK @ 187.5, 93.5, 93.5 kg ha^{-1} in combination with 0.5% micronutrients produced the highest seed cotton yield ha^{-1}, lint index, N and P uptake, and gross returns. Ahmad et al. (2016) also showed that the integrated use of macro and micronutrients caused a significant improvement in growth, yield, nutrient uptake and fiber quality of the cotton crop. Maximum improvement in plant height (61%), boll diameter (75%), number of bolls plant^{-1} (100%), and fiber strength (11%) with B @ 2 kg ha^{-1} and Zn @ 5 kg ha^{-1} along with recommended dose of NPK.

Keeping in view the significance of plant nutrition in the growth and development of cotton, the present study was planned with the objective to evaluate the integrated effect of macro and micronutrients on seed cotton yield and its components under field conditions.

MATERIALS AND METHODS

A field study was conducted at Adaptive Research Farm, Vehari, Pakistan during Kharif 2015 and 2016 on clay loam soil to assess the response of cotton varieties, MNH-886 and FH-142, to three treatments T_1: recommended dose of NPK 340-114-92 kg ha^{-1}, T_2: recommended dose of NPK + Zn 7.5 kg ha^{-1} + B 7.5 kg ha^{-1} + Fe 5 kg ha^{-1}, T_3: recommended dose of NPK + Zn 7.5 kg ha^{-1} + B 7.5 kg ha^{-1} + Fe 5 kg ha^{-1} + Cu 2.5 kg ha^{-1}. Zinc, boron, iron and copper were applied as zinc sulfate, boric acid, ferrous sulfate and copper sulfate, respectively. The experiment was laid out in split plot design with three replications having plot size of 8 × 12 m^2. Soil samples were collected from 0-30 cm depth before application of treatment fertilizers during each season.

The physical and chemical characteristics of experimental sites were determined according to methods recommended by Ryan et al. (2001) and presented in Table 1. The values demonstrated that soil was medium to heavy textured, alkaline in reaction, free of excessive soluble salts, low in organic matter, N, P, K and micronutrients to capture an economic yield. Well adopted high yielding cotton varieties MNH-886 and FH-142 were sown during second fortnight of April on a well prepared seed bed at 75 cm row to row and 22.5 cm plant to plant distances. The average maximum temperature (41.25°C and 42.8ºC), minimum temperature (27.5°C and 28.7ºC) and total rainfall (139 mm and 36 mm), during 2015 and 2016, respectively were recorded during the crop growth period. Full dose of P as single super phosphate and K as sulphate of potash were applied at planting and 340 kg N as urea was applied in five equal splits. Zinc 7.5 kg ha^{-1} + B 7.5 kg ha^{-1} + Fe 5 kg ha^{-1} and Cu 2.5 kg ha^{-1} were applied at 30 days after sowing. Pre-emergence weedicide (i.e. pendimethaline and acetachlore @ 2.5 and 1.25 L ha^{-1}, respectively) was applied to eradicate weeds. All required agronomic practices and plant protection measures were carried out accordingly. The seed cotton was harvested plot wise and finally converted into kg ha^{-1}. Ten plants from each treatment were selected at random for counting number of bolls plant^{-1} and 25 bolls were collected from each treatment for boll weight determination. The data on yield and yield components were subjected to statistical analysis and treatment differences were determined using LSD (Gomez and Gomez 1984).

Table 1 Physicochemical properties of experimental sites

Parameters	Average values
pH	8.3-8.4
ECe (dS m^{-1})	1.15-1.90
$CaCO_3$ (%)	4.6-5.8
Organic matter (%)	0.72-0.75
Available P (mg kg^{-1})	7.5-7.9
Available K (mg kg^{-1})	149-150
Available Zn (mg kg^{-1})	0.71-0.75
Available B (mg kg^{-1})	0.44-0.48
Available Cu (mg kg^{-1})	0.20-0.25
Available Fe (mg kg^{-1})	2.65-2.92
Textural class	Clay loam

RESULTS AND DISCUSSION

The results indicated that seed cotton yield and its components differed significantly ($p \leq 0.05$) with the integrated use of macro and micronutrients during 2015. Maximum seed cotton yield (1914 kg ha^{-1} for MNH-886 and 1866 kg ha^{-1} for FH-142) during Kharif 2015 was obtained from recommended dose of NPK + Zn 7.5 kg ha^{-1} + B 7.5 kg ha^{-1} + Fe 5 kg ha^{-1} + Cu 2.5 kg ha^{-1} (Table 2). The treatments behaved differently and depicted that T_3 and T_2 gave the yield at par (1914 and 1907 kg ha^{-1} for MNH-886 while, 1866 and 1838 kg ha^{-1} for FH-142), boll weight (3.28 and 3.22 g for MNH-886 and 3.12 and 3.10 g for FH-142) and number of bolls 26.2 and 24.4 plant^{-1} for MNH-886 followed by the seed cotton yield of 1880 and 1787 kg ha^{-1}, number of bolls plant^{-1} 21.2 and 20.6 and boll weight 3.04 and 2.90 g for MNH-886 and FH-142, respectively in the plots where recommended dose of NPK was applied (T_1). The data indicated significant ($p \leq 0.05$) relationship (R^2 = 0.99, 0.92) among boll weight and seed cotton yield for MNH-886 and FH-142, respectively (Figure 1). Furthermore, the hybrid cotton variety (MNH-886) performed better than FH-142. Increase in boll weight, boll number by the integrated use of NPK and micronutrients might be due to the translocation of various metabolites such as sugars, triggered by the enzymatic activation for increased photosynthetic efficiency, leading to an increase in seed cotton yield. These results are similar to Ahmad et al. (2016); Ahmed et al. (2011); Ahmed et al. (2008) who found a significant ($p \leq 0.05$) improvement in seed cotton yield and yield components such as plant height, boll weight, number of bolls plant^{-1}, boll diameter as well as fiber quality parameters including fiber strength, staple length and fiber fineness with the integrated use of NPK and micronutrients. Khan et al. (2016) also reported that exogenous application of plant nutrients increased K^+ and K^+: Na^+ ratio with the subsequent improvement in cotton growth, yield and fiber quality. Although, individual application N, P, K or Zn was effective to improve cotton growth but maximum improvement in plant growth and fiber quality characteristics of cotton was found when N, P, K and Zn were applied in combination, particularly along with farmyard manure (FYM). Different NPK application with micronutrients

Table 2 Integrated effect of macro and micronutrients on seed cotton yield and yield attributes of two cotton varieties under alkaline calcareous conditions during Kharif 2015

Treatments	Number of bolls plant^{-1}		Boll weight (g)		Seed cotton yield (kg ha^{-1})	
	MNH-886	FH-142	MNH-886	FH-142	MNH-886	FH-142
T1	21.2c	20.6c	3.04b	2.90c	1880b	1787d
T2	24.4b	23.2b	3.22a	3.10b	1907a	1838c
T3	26.2a	23.8b	3.28a	3.12b	1914a	1866b
LSD value ($p \leq 0.05$)	1.11		0.07		15.37	

Means not sharing a common letter in a column are significant at 5% probability level; T_1: Recommended dose of NPK 340-114-92 kg ha^{-1}, T_2: Recommended dose of NPK + Zn 7.5 kg ha^{-1} + B 7.5 kg ha^{-1} + Fe 5 kg ha^{-1}, T_3: Recommended dose of NPK + Zn 7.5 kg ha^{-1} + B 7.5 kg ha^{-1} + Fe 5 kg ha^{-1} + Cu 2.5 kg ha^{-1}

Table 3 Integrated effect of macro and micronutrients on seed cotton yield and yield attributes of two cotton varieties under alkaline calcareous conditions during Kharif 2016

Treatments	Number of bolls plant^{-1}		Boll weight (g)		Seed cotton yield (kg ha^{-1})	
	MNH-886	FH-142	MNH-886	FH-142	MNH-886	FH-142
T1	25d	24d	2.98c	2.76f	2191C	2074F
T2	27.8b	26.2c	3.10b	2.84e	2230B	2130E
T3	30.2a	26.6c	3.19 a	2.92d	2266A	2159D
LSD value ($p \leq 0.05$)	1.17		0.05		14.72	

Means not sharing a common letter in a column are significant at 5% probability level; T_1: Recommended dose of NPK 340-114-92 kg ha^{-1}, T_2: Recommended dose of NPK + Zn 7.5 kg ha^{-1} + B 7.5 kg ha^{-1} + Fe 5 kg ha^{-1}), T_3: Recommended dose of NPK + Zn 7.5 kg ha^{-1} + B 7.5 kg ha^{-1} + Fe 5 kg ha^{-1} + Cu 2.5 kg ha^{-1}

also influenced number of bolls, boll weight and seed cotton yield significantly ($p \leq 0.05$) during Kharif 2016. Highest seed cotton yield (2266 kg ha^{-1} for MNH-886 and 2159 kg ha^{-1} for FH-142) during Kharif 2016 was yielded from recommended NPK + Zn 7.5 kg ha^{-1} + B 7.5 kg ha^{-1} + Fe 5 kg ha^{-1} + Cu 2.5 kg ha^{-1} (Table 3). The results behaved differently compared to the results of Kharif 2015 and depicted that T3 proved to be better in seed cotton yield (2266 kg ha^{-1} for MNH-886 and 2159 kg ha^{-1} for FH-142), number of bolls plant^{-1} (30.2 for MNH-886 and 26.6 for FH-142) and boll weight (3.19 g for MNH-886 and 2.92 g for FH-142) followed by the seed cotton yield of 2230 kg ha^{-1} for MNH-886 and 2130 kg ha^{-1} for FH-142, number of boll Plant^{-1} 27.8 for MNH-886 and 26.2 for FH-142 and boll weight 3.10 g for MNH-886 and 2.84 g for FH-142 in T_2 where recommended NPK + Zn 7.5 kg ha^{-1} + B 7.5 kg ha^{-1} + Fe 5 kg ha^{-1} was applied against the minimum seed cotton yield of 2191 kg ha^{-1} for MNH-886 and 2074 kg ha^{-1} for FH-142, number of bolls plant^{-1} 25 for MNH-886 and 24 for FH-142 and boll weight 2.98 g for MNH-886 and 2.76 g for FH-142 with T_1 (only NPK). When compared the both cotton varieties, MNH-886 performed better than FH-142 at all fertilizer treatments. The results of Kharif 2016 were found better than Kharif 2015. Significant relationship (R^2 = 0.99, 0.96) was revealed between boll weight and seed cotton yield for MNH-886 and FH-142, respectively as presented in Figure 2 which elucidated that seed cotton yield was linearly increased with increase in boll weight. The results are in agreement with Cioroi and Florea (2003; Mousavi (2011); Ravikiran et al. (2012) who concluded that adequate and balanced supply of plant nutrients is vital for better seed cotton yield and fiber quality, and deficiency in any single nutrient may hamper plant growth and seed cotton yield. However, the mineral nutrition of cotton depends on both the cotton root's ability to explore the soil and the ability of soil to supply nutrients to growing roots (Bisson et al. 1994).

CONCLUSION

It was found that judicious and balanced use of micro and macronutrients in Bt-cotton substantially increased the number of bolls plant^{-1}, boll weight and seed cotton yield. The results also showed that the combination of B @ 7.5 kg ha^{-1}, Zn@ 7.5 kg ha^{-1}, Fe @ 5 kg ha^{-1} and Cu @ 2.5 kg ha^{-1} along with recommended dose of NPK significantly ($p \leq 0.05$) increased the yield and yield components of cotton than recommended NPK application alone. When compared both cotton varieties, MNH-886 performed better than FH-142. Furthermore, the increase in seed cotton yield and yield attributes was more pronounced in Kharif 2016 compared to Kharif 2015.

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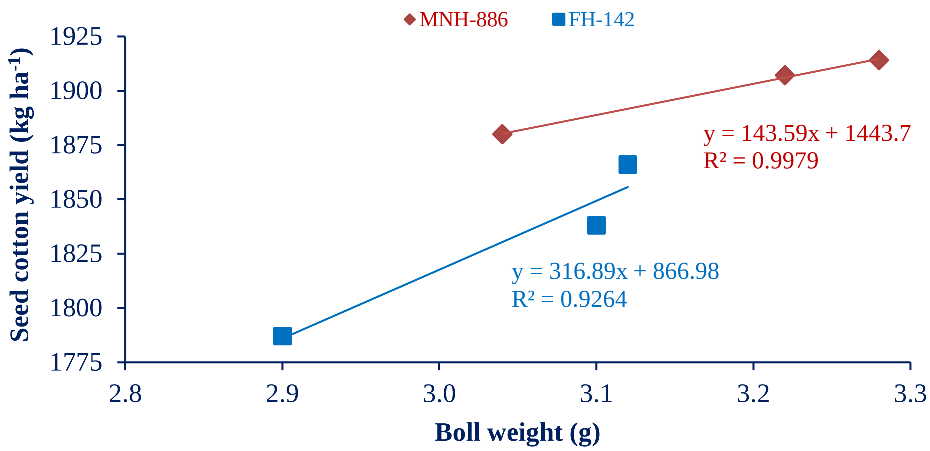

Figure 1 Relationship between boll weight and seed cotton yield for year 2015

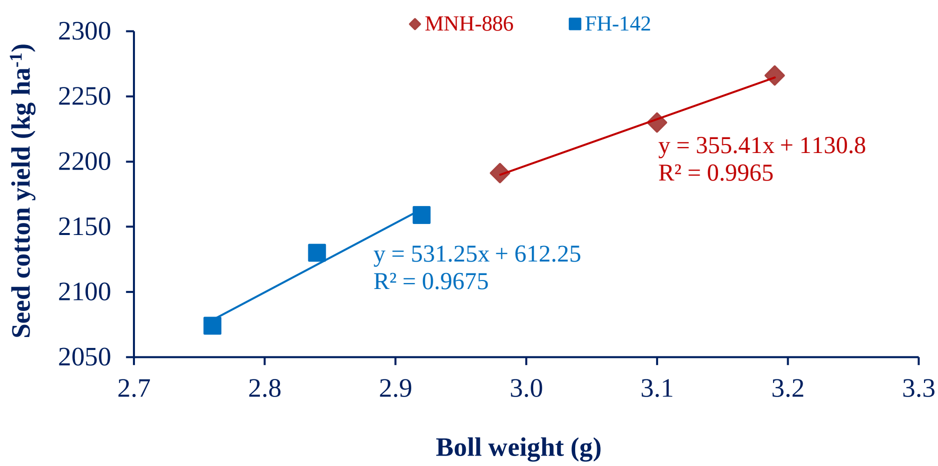

Figure 2 Relationship between boll weight and seed cotton yield for year 2016

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