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RESEARCH ARTICLE

Effect of Supplemental Foliar-Applied Potassium on Cotton (*Gossypium hirsutum* L.) Yield and Lint Quality under Drought Stress

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ABSTRACT

A study to determine the effect of supplemental foliar-applied potassium on cotton (*Gossypium hirsutum* L.) yield and lint quality under drought stress was conducted using six cotton varieties, three drought tolerant (CIM-496, CIM-473 and FH-1200) and three drought sensitive (CIM-534, CIM-554 and FH-945) and two levels of supplemental foliar- applied potassium (0 and 1 %). The experiment was conducted in lysimeter for consecutive two years with four water levels i.e. well watered (100% FC), medium watered (80% FC), low watered (60% FC) and soil stored moisture (40% FC). Results indicated that tolerant cotton variety maintained higher yield and lint quality at all drought stress levels. Supplemental foliar application (1%) of potassium significantly improved the drought tolerance potential and yield in all cotton varieties. However, cotton variety CIM-473 ranked first in fiber strength and fiber length whereas fiber micronaire was higher in cotton variety CIM-496. The variety FH-1200 with the foliar application (1%) of potassium produced the highest cotton yield. Foliar application of 1% potassium as supplementary source under drought stress conditions was found helpful in improving yield and quality of cotton.

INTRODUCTION

Crop production in water-limited environments depends upon the intensity and the pattern of drought, which vary from year to year (Soriano et al., 2004). Drought stress affects plant growth and development by inhibiting cell expansion resulting in reduced biomass production (Ashraf et al., 1994), disturbing different metabolic activities of plants (Khan et al., 1999; Lawlor and Cornic, 2002) by altering nutrient balance (Kidambi et al., 1990) and inhibiting enzyme activities (Ashraf et al., 1995). Cotton, though relatively a drought tolerant crop is still affected by drought like other crops and water stress has marked adverse effects on morphological, biochemical, physiological and yield attributes of cotton (Patil et al., 2011).

Cotton yield and quality is negatively affected by potassium deficiency (Cassman et al., 1990). Cotton requires 3 to 5 kg potassium per day per hectare during boll fill and on an average mature cotton crop is estimated to require a total of 110 to 250 kg potash per hectare (Halevy, 1976). Potassium plays an important role in photosynthesis, water relations, balance between cations, translocation of carbohydrates and resistance against insects and diseases (Brar and Tiwari 2004). Potassium contributes for water relations of plants making them survive under water deficit conditions as it is the major osmoticum in plants. It accumulates in cell and enhances water uptake so maintains the cell turgor required for growth and development (De La Guardia and Benloch, 1980) and stomatal opening (Fischer and Hsiao, 1968). Mullins and Burmester (1991) stated that the duration of active growth, eventual size of plants, and the amount of potassium taken up and removed ranges from 1 to 1.5 kg per acre per day from the soil plant system by harvesting can affect potassium availability and total crop potassium demand. In general, higher boll loads and higher seed cotton yields requires and depletes more potassium from the soil system than with lower boll loads and yields.

Soils in Pakistan are naturally high in potassium. Even then to maintain soil potassium at optimum levels, it is inevitable to supplement cotton crop with additional sources of potassium especially under drought stress when nutrient absorption and uptake at root level is limited due to water shortage in the soil. Foliar application of potassium in many crop species at or near the time when supply of nutrients either becomes deficient or needed the most, has gained popularity in recent years (Weir, 1998). A reasonable research work on improving use efficiency of soil-applied potassium under drought stress has been reported in the literature. However, very little information is available on the interactive effects of foliar-applied and soil-applied potassium in alleviating the adverse effects of drought stress especially in cotton. The present study, therefore, was conducted with the objective to determine the effect of supplemental foliar-applied potassium on cotton (*Gossypium hirsutum* L.) yield and lint quality under drought stress.

MATERIALS AND METHODS

The experiments were conducted at Nuclear Institute of Agriculture and Biology (NIAB), Faisalabad, Pakistan during 2009-2010 in lysimeters using sandy loam soil. Before sowing soil tests showed soil pH 7.56, EC_e 1.28 dS m^{-1}, saturation 32 %, available K 2.39 and available P 1.96. The soil texture was determined with the hygrometer method (Dewis and Freitas, 1970). The physiochemical characteristics (Electrical conductivity, pH and ion contents) of the soil used for this study were determined according to methods described by Jackson (1962). The experiments were laid out in completely randomized design with three replications. Four different water levels as well watered (100% Field Capacity; FC), medium watered (80% FC), low watered (60% FC) and soil stored moisture (40% FC) were maintained in which 1% foliar potassium was sprayed to evaluate its effect on seed cotton yield and lint quality. Water meter was used to measure the amount of irrigation applied at regular intervals in the lysimeter tanks. Potassium sulphate was used as a K source. Recommended dose of NPK (120-60-60 kg ha^{-1}) was applied at the time of planting. Six cotton varieties including three drought tolerant (CIM-473, CIM-496 and FH-1200) and three drought susceptible (FH-945, CIM-534 and CIM-554) were used in these experiment. Data for yield and fiber quality were recorded at maturity. The fiber quality parameters (Fiber micronaire, fiber strength and fiber length)) were recorded according to ASTM Committeen(1997) using high Volume Instrument (HVI-900SA), a fiber testing system manufactured by M/S. Zellweger Uster Ltd. (Switzerland). Data were analyzed statistically using analysis of variance technique and the STATISTICA computer program was used for this purpose. The Least Significant Difference (LSD) test at 5% probability level was used to assess the differences among significant means (Steel and Torrie, 1984).

RESULTS

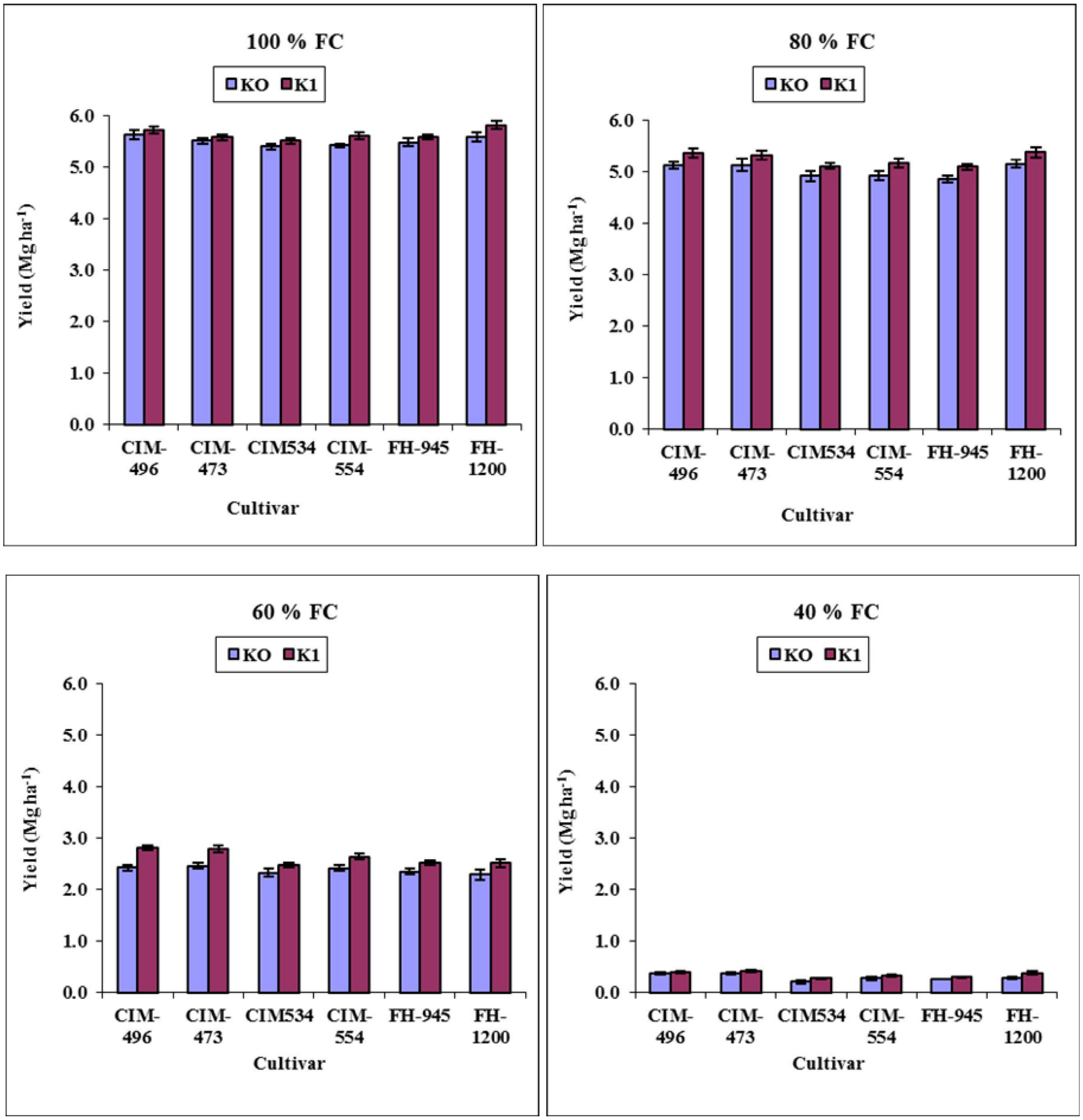
Seed cotton yield (M g ha^{-1})

Moisture stress, cultivars and foliar application of potassium as supplement to soil-applied potassium had a significant effect on seed cotton yield in both (2009-2010) years of study. The maximum mean seed cotton yields of 5.57 Mg ha^{-1} and 5.48 Mg ha^{-1} were observed in control (100% FC) during 2009 and 2010, respectively (Figs. 1a and b). Seed cotton yield decreased with increasing moisture stress and was the minimum (0.32 Mg ha^{-1} in 2009 and 0.34 Mg ha^{-1} in 2010) in severe water stress treatment (40% FC). In 2009, the maximum mean seed cotton yield (3.48 Mg ha^{-1}) was recorded for cultivar CIM-496 followed by CIM-473, FH-1200, CIM-554, FH-945 and CIM-534 which showed seed cotton yields of 3.45, 3.43, 3.35, 3.31 and 3.28 Mg ha^{-1}, respectively. For the year 2010, the maximum seed cotton yield of 3.43 Mg ha^{-1} was observed for cotton cultivar CIM-473 followed by in descending order by FH-1200, CIM-496, CIM-554, CIM-534 and FH-945 which showed seed cotton yields of 3.42, 3.40, 3.33, 3.29 and 3.28 Mg ha^{-1}, respectively. Foliar application of 1% potassium proved better than control in both years and the seed cotton yields recorded for this treatment (K1) were 3.46 Mg ha^{-1} and 3.44 Mg ha^{-1}, respectively in 2009 and 2010. In 2009, the cultivar FH-1200 produced the maximum mean yield of 5.82 Mg ha^{-1} in combination with 1% potassium application whereas during 2010 the cultivar CIM- 473 in combination with 1 % potassium gave the maximum seed cotton yield of 5.66 Mg ha^{-1}.

Lint Quality

During 2009 and 2010, the moisture stress, potassium application and cultivar had a significant effect on micronaire. The maximum mean micronaire values (4.178 and 4.264) were observed in control (100% FC) in both years (Figs. 2a and b) which decreased with increasing moisture stress in all cultivars. Among cotton cultivars, the maximum mean micronaire values of 3.979 in 2009 and 3.987 in 2010 were observed for cotton cultivar CIM-496. In case of potassium application, the maximum mean value of micronaire (3.96) was observed with K1 (1 % foliar applied potassium) and the minimum micronaire value of 3.64 was observed with K0. In both years of study, the micronaire values in cotton cultivar CIM-496 were the maximum in control (100 % FC) in combination with 1% foliar application of potassium (Fig 2 and b).

Fiber strength was significantly affected by the moisture stress; potassium application and cultivar were significantly different from each other during both years of study (Figs. 3a and b). In case of moisture



*Error bars represent values of standard error.

Fig. 1(a): Effect of moisture stress and foliar applied potassium on seed cotton yield of different cotton cultivars during 2009

K0 = No foliar application of potassium

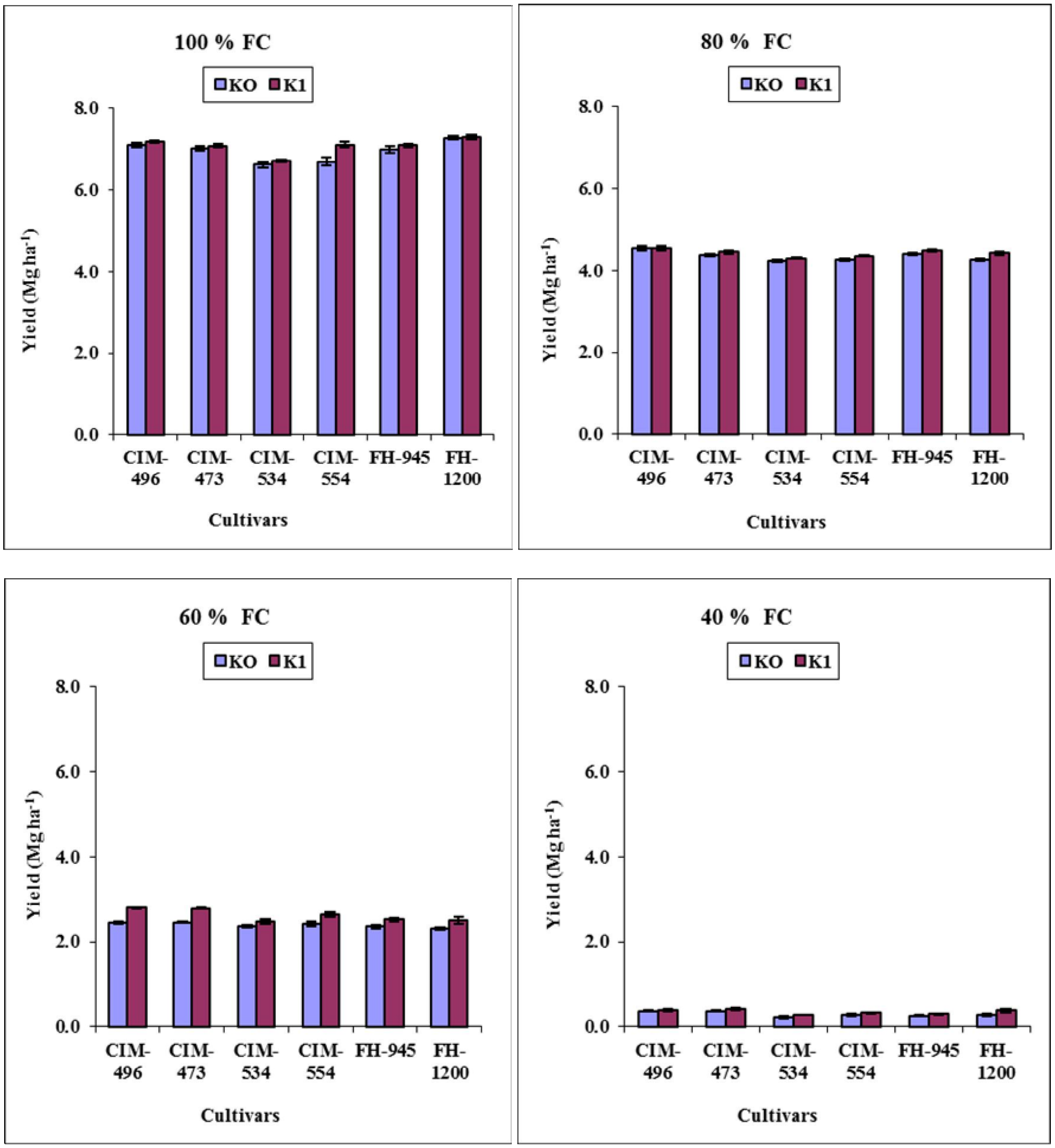
K1 = Foliar application of 1% potassium

Drought resistant varieties: CIM-496, CIM-473 and FH-1200

Drought sensitive varieties: CIM-534, CIM-554 and FH-945

stress the maximum mean values of fiber strength (25.75 g tex^{-1} in 2009 and 25.27 g tex^{-1} in 2010) were observed in control (100% FC). The fiber strength decreased with increasing moisture stress from 100% FC level to 40 % (Figs. 3a and b). Among cultivars the maximum fiber strength value of 23.50 g tex^{-1} was recorded for the cultivar CIM-473 in both years. Foliar application of 1% potassium produced lint with higher fiber strength than non-sprayed treatments in all cultivars in both years of study. The maximum mean value (26.70 g tex^{-1} in 2009 and 26.70 g tex^{-1} in 2010) of fiber strength were observed with cultivar CIM-473 in combination with 1 % foliar applied potassium at 100 % FC (Figs. 3 a and b).

Fiber length differed significantly with moisture stress, potassium application and cultivars and all interaction

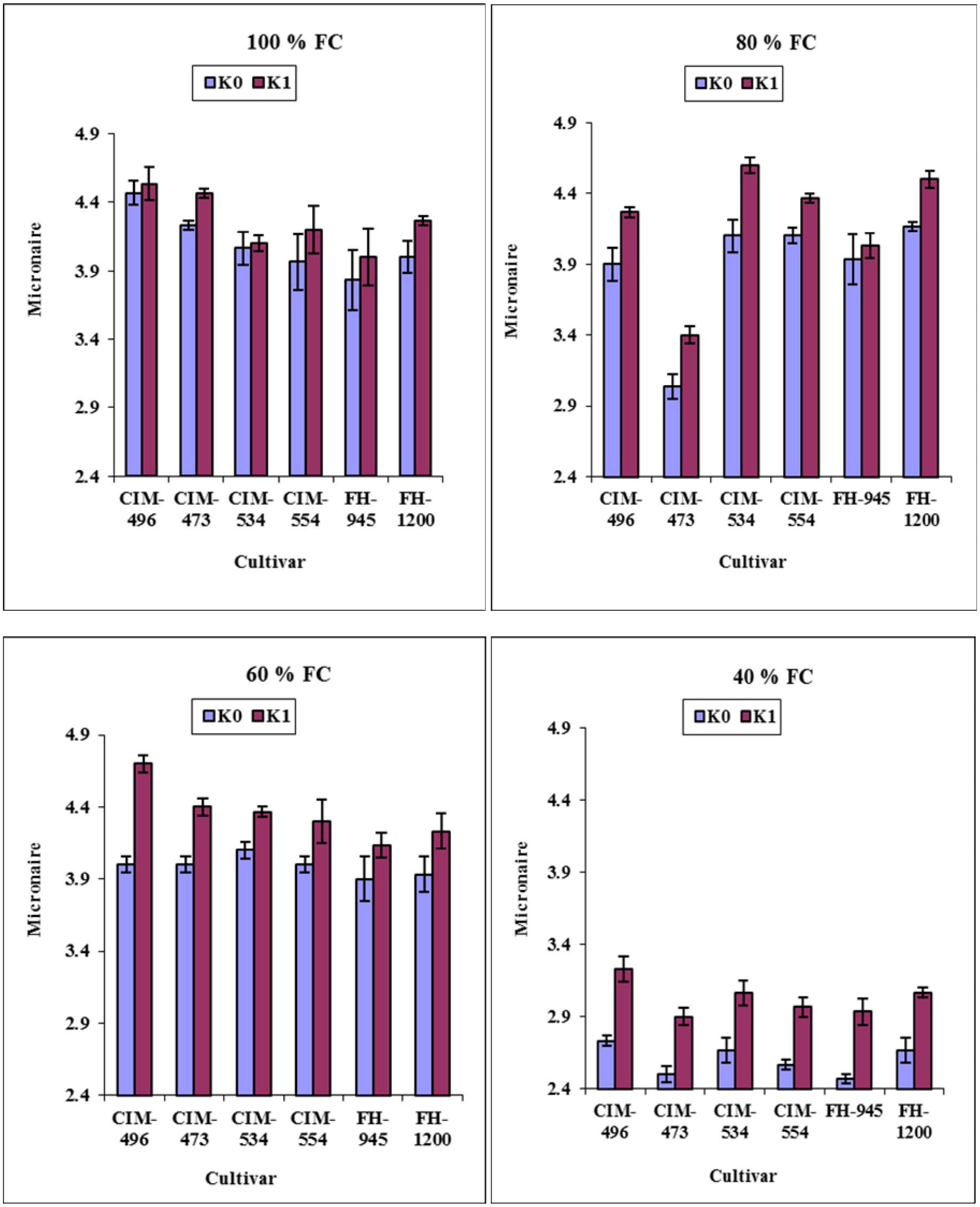


*Error bars represent values of standard error.

Fig. 1(b): Effect of moisture stress and foliar applied potassium on seed cotton yield of different cotton cultivars during 2010.

K0 = No foliar application of potassium
K1 = Foliar application of 1% potassium
Drought resistant cultivars: CIM-496, CIM-473 and FH-1200
Drought sensitive cultivars: CIM-534, CIM-554 and FH-945

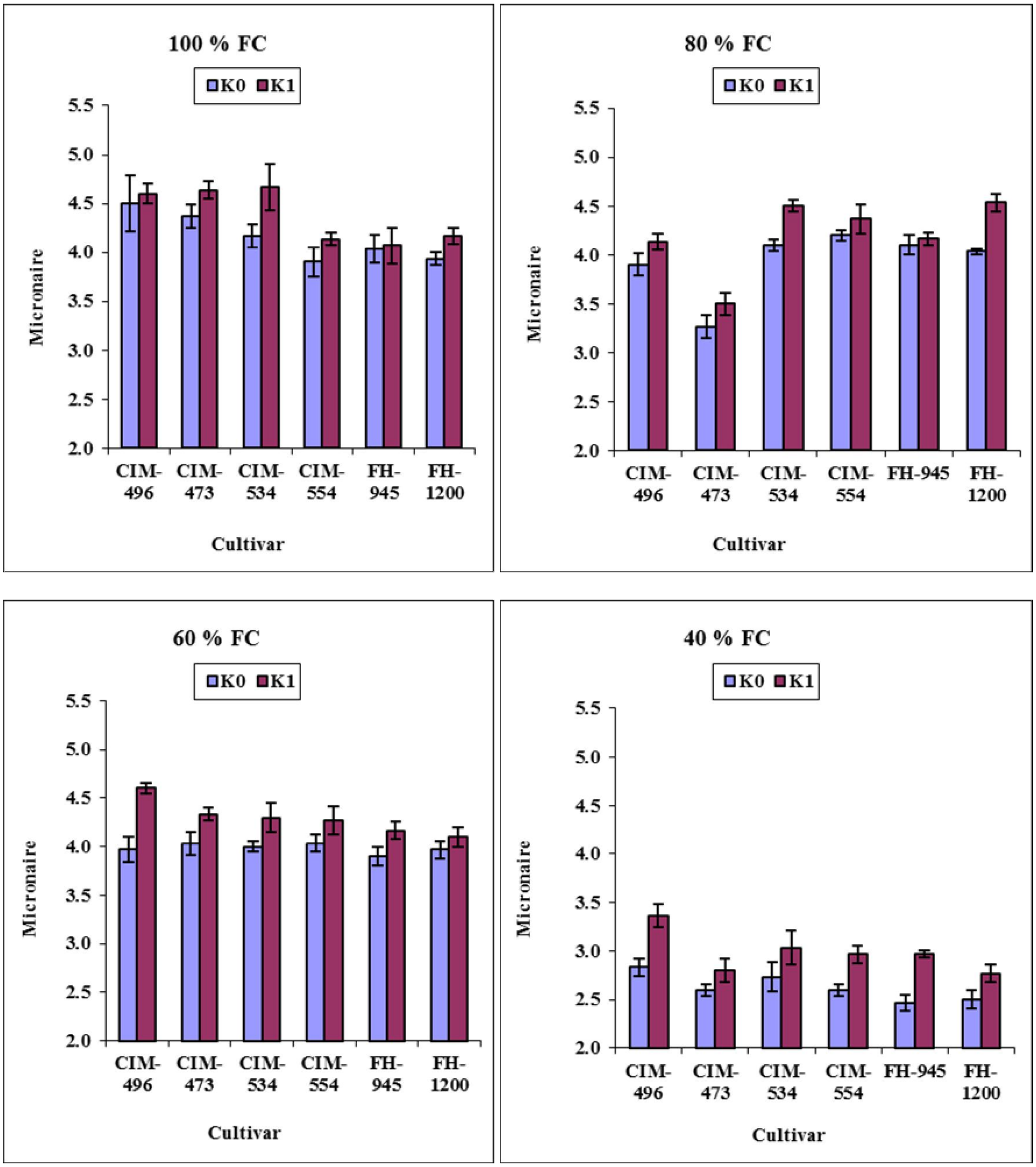
were statistically significant (Figs. 4a and b). In case of moisture stress the maximum mean values of fiber strength (27.98 mm in 2009 and 27.96 mm) was observed with 80% FC and it was statistically at par with moisture stress level of 100% FC. It was followed in descending order by 100, 60 and 40% FC which was 27.90, 26.71 and 23.56, respectively (Figs. 4a and b). In case of cultivars, the maximum mean values of fiber length (26.85mm in 2009 and 27.34 mm in 2010) were observed in cotton cultivar CIM-473. Similarly the maximum mean values of fiber length (28.66 mm in 2009 and 28.65 mm in 2010) were observed with K1 in 80 % FC level and it was statistically similar with the fiber length values recorded for control (100% FC).



*Error bars represent values of standard error.

Fig. 2(a): Effect of moisture stress and foliar applied potassium on micronaire of different cotton cultivars during 2009

K0 = No foliar application of potassium
K1 = Foliar application of 1% potassium
Drought resistant cultivars: CIM-496, CIM-473 and FH-1200
Drought sensitive cultivars: CIM-534, CIM-554 and FH-945



*Error bars represent values of standard error.

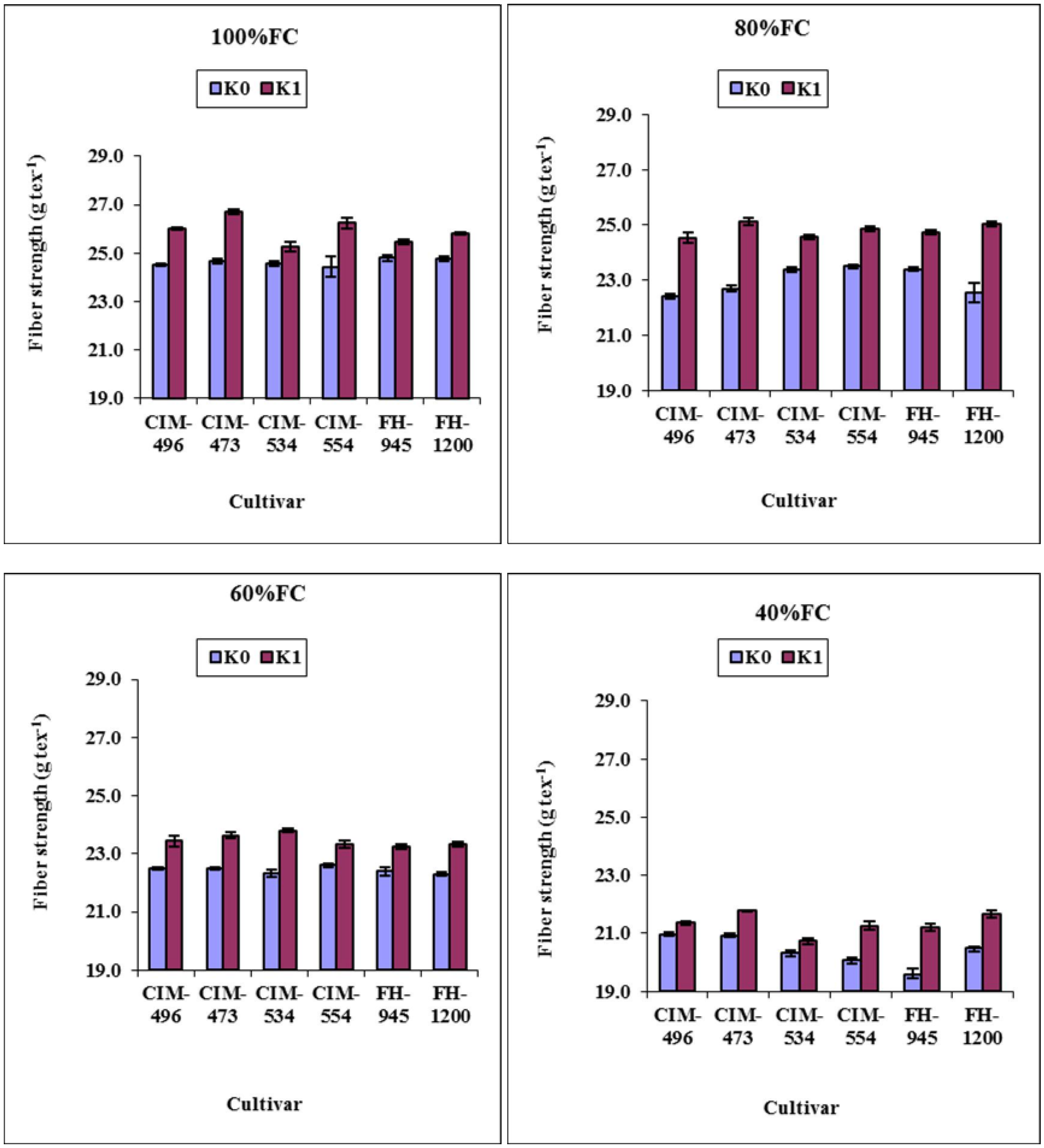
Fig. 2(b): Effect of moisture stress and foliar applied potassium on micronaire of different cotton cultivars during 2010

K0 = No foliar application of potassium
K1 = Foliar application of 1% potassium
Drought resistant cultivars: CIM-496, CIM-473 and FH-1200
Drought sensitive cultivars: CIM-534, CIM-554 and FH-945

DISCUSSION

The results of present study showed that the foliar application of potassium under water stress reduced the stress intensity and improved the yield (Figs. 1a and b).

In case of micronaire (Figs. 2 a and b), the cultivar CIM-496 performed best under 100, 60 and 40% FC with potassium application while cultivar CIM-534 showed best result under 80% FC with potassium application during first year. During second year, the

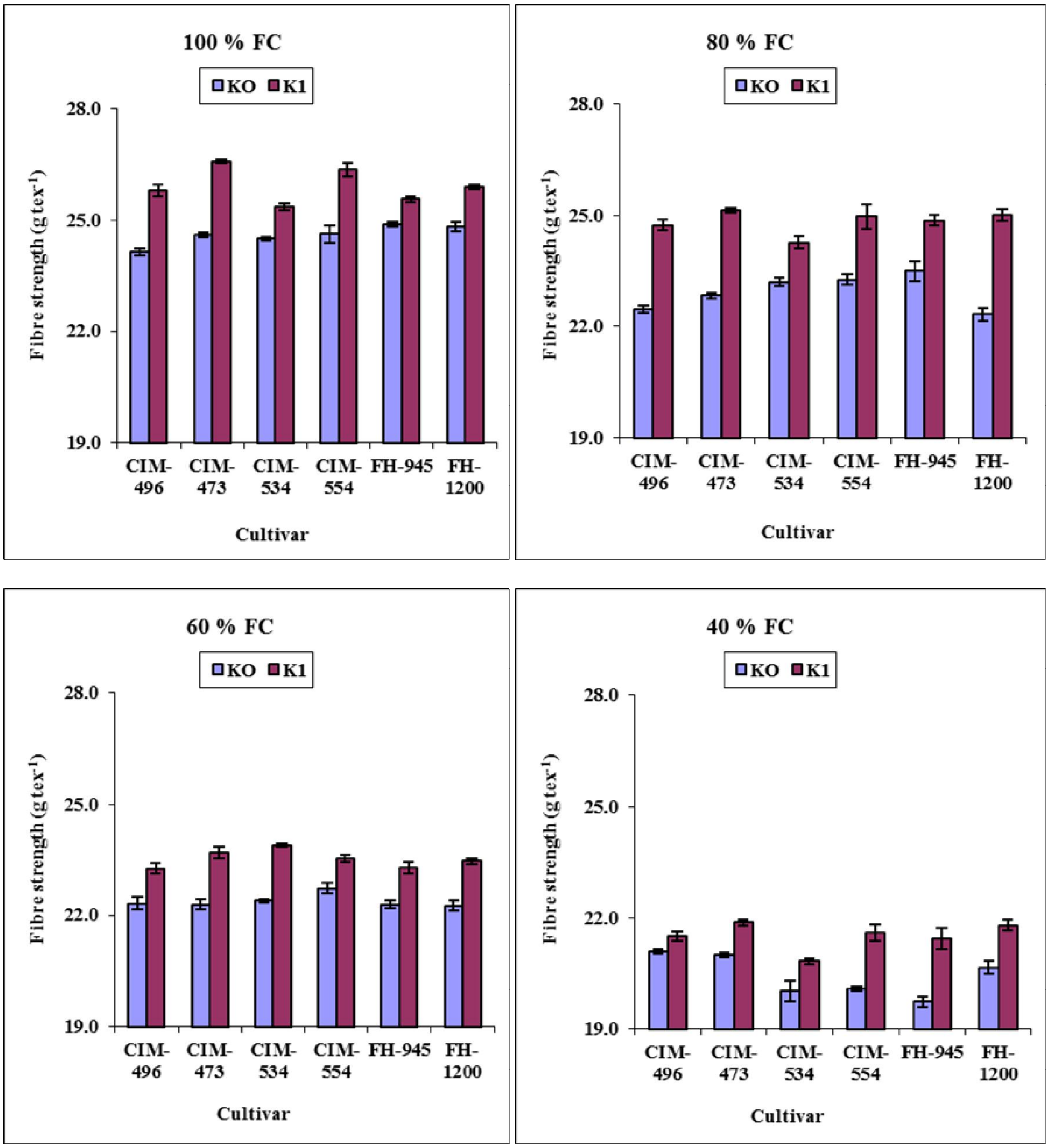


*Error bars represent values of standard error.

Fig. 3 (a): Effect of moisture stress and foliar applied potassium on fiber strength of different cotton cultivars during 2009

K0 = No foliar application of potassium
K1 = Foliar application of 1% potassium
Drought resistant cultivars: CIM-496, CIM-473 and FH-1200
Drought sensitive cultivars: CIM-534, CIM-554 and FH-945

cultivar CIM-496 performed best at 60 and 40 % FC with 1% foliar potassium fertilization. At 100 and 80% FC, the cultivars CIM-534 and FH-1200 maintained micronaire with 1 % foliar potassium application. Our results are in line with Roland et al. (1999) who reported that number of open bolls increased after foliar potassium nitrate application. Results were also supporting foliar KNO_3 by increasing quality of fiber. In case of fiber strength (Figs. 3 a and b) the cultivars CIM-473 and CIM-534 gave best result under 100, 60, 40 and 80% FC with 1 % foliar potassium fertilization, respectively, during the first year while in second year CIM-473 performed best at 100, 80 and 40% FC with 1 % foliar applied potassium. The cultivar CIM -534 only

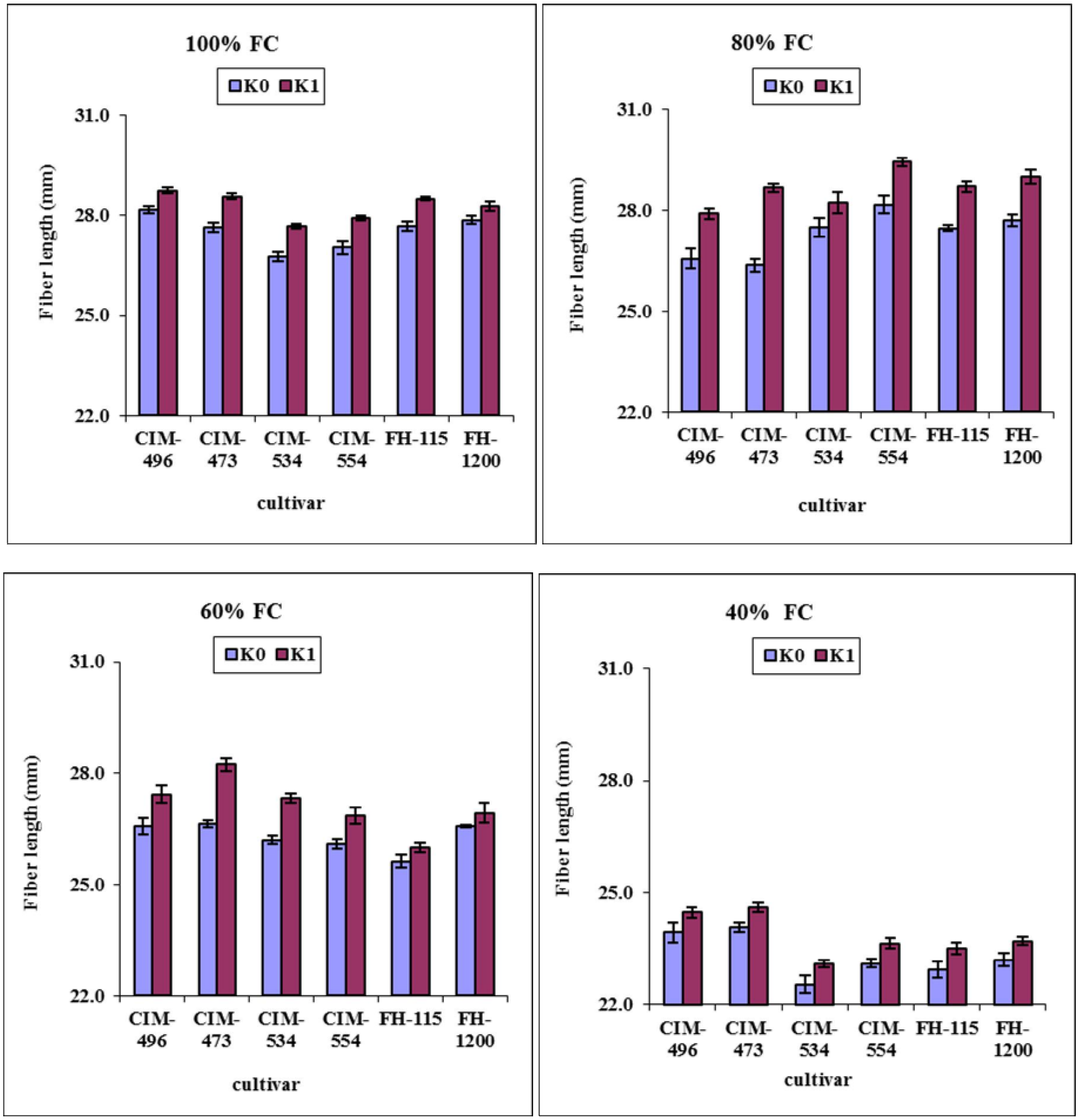


*Error bars represent values of standard error.

Fig. 3 (b): Effect of moisture stress and foliar applied potassium on fiber strength of different cotton cultivars during 2010

K0 = No foliar application of potassium
K1 = Foliar application of 1% potassium
Drought resistant cultivars: CIM-496, CIM-473 and FH-1200
Drought sensitive cultivars: CIM-534, CIM-554 and FH-945

gave best result at 60% FC with potassium fertilization during second year. Results regarding the fiber length (Fig 4.a and b) showed that the cultivar CIM-554 performed best at 80 % FC with potassium fertilization through foliage. While at 100, 60 and 40 % FC, the cultivars FH-1200 and CIM- 473 gave maximum fiber length during first year, respectively. During the second year, the cultivar CIM-473 gave maximum fiber length at 100, 60 and 40% FC with foliar potassium application while at 80% FC, the cultivar FH-1200 showed maximum fiber length with 1% foliar applied potassium. The results of present study indicate that

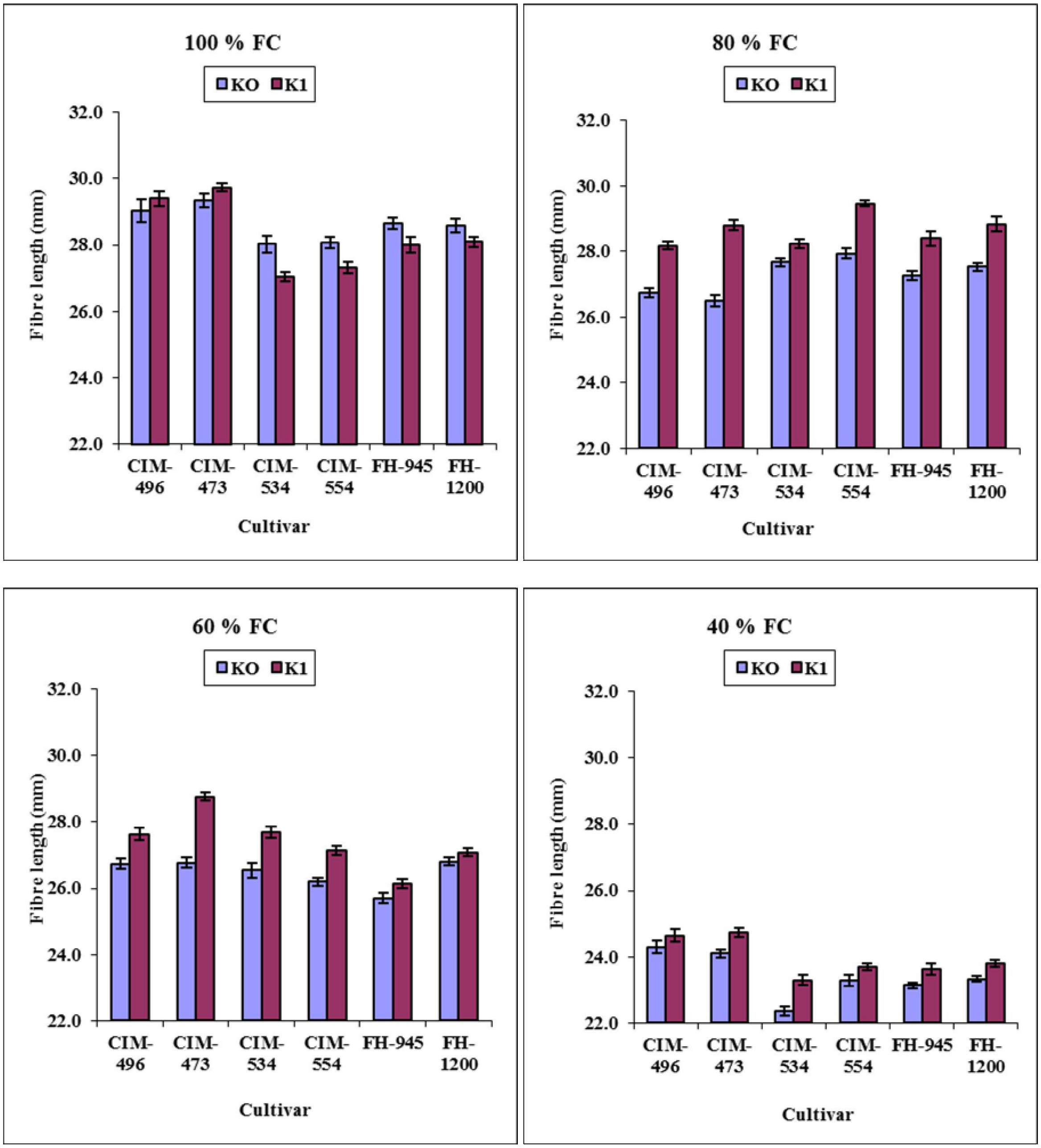


*Error bars represent values of standard error.

Fig. 4(a): Effect of moisture stress and foliar applied potassium on fiber length of different cotton cultivars during 2009

K0 = No foliar application of potassium
K1 = Foliar application of 1% potassium
Drought resistant cultivars: CIM-496, CIM-473 and FH-1200
Drought sensitive cultivars: CIM-534, CIM-554 and FH-945

lint properties, such as lint length and micronaire were reduced when soil moisture deficits grew large, which is similar to the findings of others (Guinn and Mauney, 1984). The fact that some of the lint components did not respond to moisture stress is similar to results reported by Kimball and Mauney (1993) which is probably because of genotype differences and in the degree of moisture deficit stress that were developed in present study. Different findings have been reported about fiber strength by some workers. Pettigrew et al. (1996) found that the potassium deficiency reduced lint yield. Gormus (2002) found good response in case of fiber quality parameters after the application of potassium at early boll development stage. Li et al.



*Error bars represent values of standard error.

Fig. 4(b): Effect of moisture stress and foliar applied potassium on fiber length of different cotton cultivars during 2010

K0 = No foliar application of potassium
K1 = Foliar application of 1% potassium
Drought resistant cultivars: CIM-496, CIM-473 and FH-1200
Drought sensitive cultivars: CIM-534, CIM-554 and FH-945

(1999) reported that cellulose synthesis and dry matter accumulation were increased by potassium application in cotton. Similarly, Zakaria et al. (2006) also stated that by increasing nitrogen fertilization either foliar or soil application, lint yield is increased significantly. In conclusion the adverse effects of drought stress on cotton can be alleviated with the foliar application of potassium. Furthermore, improved yield of cotton varieties CIM-473, FH-1200 and CIM-496 in comparison with varieties CIM-554, FH-945 and CIM-

534 under water stress conditions was due to their genetic potential and competitive effect of potassium.

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