Research Article

Effect of Potassium Sources on the Growth, Yield and Fruit Quality of Tomato Cultivars

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Abstract | The research was conducted to investigate the effect of various combinations of potassium from organic and inorganic sources on the growth, yield and fruit quality of two tomato cultivars i.e., Falcon and Rio Grande for two years. The response of tomato cultivars was assessed to six combinations viz. 0-0 (control), 100-0, 75-25, 50-50, 25-75 and 0-100% of poultry manure (PM) and Sulphate of Potash (SOP). All the factors (K-sources, cultivars and years) alone and in combination significantly affected the growth, yield and fruit quality of tomato. The highest number of leaves plant^{-1} (75.25) and yield (49.25 t ha^{-1}) were gained by Falcon in 50-50 treatment during, 2010. However, the plant height (134 cm) and fruit size (147.1 cm^3) were higher at 25-75 and 75-25 treatment, respectively. Whereas, the less number of leaves plant^{-1} (15), plant height (28.25 cm), fruit size (92.3 cm^3) and tomato yield (7.5 t ha^{-1}) were recorded for Rio Grande in control during, 2009. The fruit weight (69.25 g) and TSS (4.55 °Brix) were higher in Rio Grande cultivar in treatment 75-25 and 50-50, respectively. It is concluded that a combination of PM and SOP at 50-50 and 75-25 ratio may be used as an optimum fertilization dose for obtaining higher yield and improved fruit quality of tomato crop.

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Keywords | Tomato, Potassium, Poultry manure, Yield, Fruit quality and Inorganic

Introduction

Tomato (*Solanum lycopersicon* Mill) is widely cultivated crop in Pakistan. Pakistan produced 577.9 thousand tons of tomato during, 2011-12 with an average yield of 10.1 t ha^{-1}. This average yield is very low from the other neighbouring countries i.e., China and India (FAO, 2012). The main causes of the low production are the unavailability of high yielding cultivars, costly planting materials and lack of awareness in the use of integrated nutrients and pest management practices. The poor resources farmers are unable to use the chemical fertilizer in optimum quantity due to high cost (Rahman, 2004). The alternative to chemical fertilizer is organic manures especially poultry manure, which provide a portion, or all, of the plant mineral requirements (John et al., 1999). It contains N, P and K and trace elements in higher quantity (Bolan et al., 2010). Potassium is present more abundantly in the soil than phosphorus but requires in large amounts by plants, being the second most concentrated nutrient in plant leaves and shoots after nitrogen. Potassium plays an important role in tomato fruit quality by involves in metabolic processes, such as the enzyme activation, synthesis of proteins, membrane transport processes and the generation of turgor pressure (Dorais et al., 2001). Furthermore, it involves in the translocation of photosynthates from sources to sinks (Cakmak et al., 1994). The removal of nutrients by crops and the addition of nutrients to soil from fertilizers or manure plays key role in the nutrient balance of a cropping system (Blaise et al., 2005).

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The organic manure is very helpful in supplying potassium to soils on long term basis (Lin, 2010) and the combine application of poultry manure and potassium fertilizer increased the nutrients uptake from soil (Mottaghian et al., 2008). In contrast to mineral fertilizer, organic manures add organic matter to soil resulting in improved soil structure, higher nutrient retention, enhanced soil moisture holding capacity and increased soil micro flora and fauna activity (Zeidan, 2007). The organic fertilizer supply the nutrients in long run as compared to inorganic fertilizer, which are readily available and cannot sustained for long time (Vernon, 1999).

Previous studies have shown that the combine application of commercial organic manure and chemical fertilizers enhanced the quantity and quality of vegetables (Kong and Ni, 2006). These observations allowed us to hypothesize that there might have been a synergistic influence of organic and inorganic K sources on the yield and mineral contents of tomato fruit. Therefore, this study was conducted to investigate the effect of poultry manure and SOP amendments on the yield and mineral profile of Rio Grande and Falcon tomato cultivars.

Materials and Methods

Experimental site and soil characterization

The study was conducted in district Swat during summer, 2009 and repeated in 2010. The climatic conditions of the site was temperate to warm with low average monthly rainfall (9 mm) in 2009 and adequate (154 mm) in 2010 during the cropping season. The main chemical composition of the poultry manure (PM) and soil are presented below:

- Poultry Manure (2009-10): Organic Matter (OM) (3.45-3.25%), N (3.36-3.15%), P (1.80-1.74%), K (2.65-2.91%) and soil pH (7.5-7.44).
- Soil (2009-10): OM (0.69-1.14%), N (0.034-0.055%), P (0.0086-0.0094%), K (0.019-0.021%) and soil pH (6.91-6.82).

Experimental design and crop fertilization

The experiment was laid out in Randomized Complete Block Design (RCBD) with three factors and replicated four times. The factors included K-source, PM and Sulphate of Potash (SOP), cultivar (Falcon and Rio Grande) and two consecutive years of cultivation. The tomato cultivars were fertilized with PM and SOP in various combinations *viz.* 0-0 (control), 100-0, 75-25, 50-50, 25-75, 0-100 in percent. Each of these combinations provided 60 kg ha^{-1} of K to the crop. The experimental plot was ploughed and disked three times, and the beds were prepared manually. The PM was applied one month before seedlings transplantation, while the SOP was applied at time of seedlings transplantation. The seedlings were transplanted on both sides of two-meter wide and five meter long beds with a distance of 60 cm on the bed. The plants were irrigated just after seedling transplantation and the crop was irrigated accordingly during the whole cropping season. The N (80 kg ha^{-1}) and P (60 kg ha^{-1}) requirements of the crop was fulfilled from PM, Urea and Triple Super Phosphate (Siddiq et al., 2009). Weeds were controlled manually in all plots. Corrective measures were taken for the control of insect pest and diseases. The crop was measured for the following parameters at different growth stages.

Number of leaves plant^{-1}

The number of leaves plant^{-1} was counted and recorded their means by taken five randomly plants from each sub-plot and calculated their average.

Plant height (cm)

The data pertaining to plant height was recorded in centimetres at the maximum stage of growth by measuring the plant from soil surface to the tip of the main stem by taking five randomly plants from each of sub-plot and after their means were calculated.

Fruit Size (cm^3)

At least five fruits were randomly taken from each treatment and their volume was recorded with the displacement of water (ml) as 1ml = 1cm^3 and calculated their average.

Fruit weight (g)

The average weight of the individual fruit was measured with the help of electronic balance in grams by weighting five randomly taken tomato fruits from each treatment and the means was calculated.

Yield (t ha^{-1})

All the tomato fruit were weighed at each harvest and the total yield was calculated in tones per hectare.

Fruit juice pH

Tomato fruits from each treatment were randomly taken and juice was extracted with juice extractor and

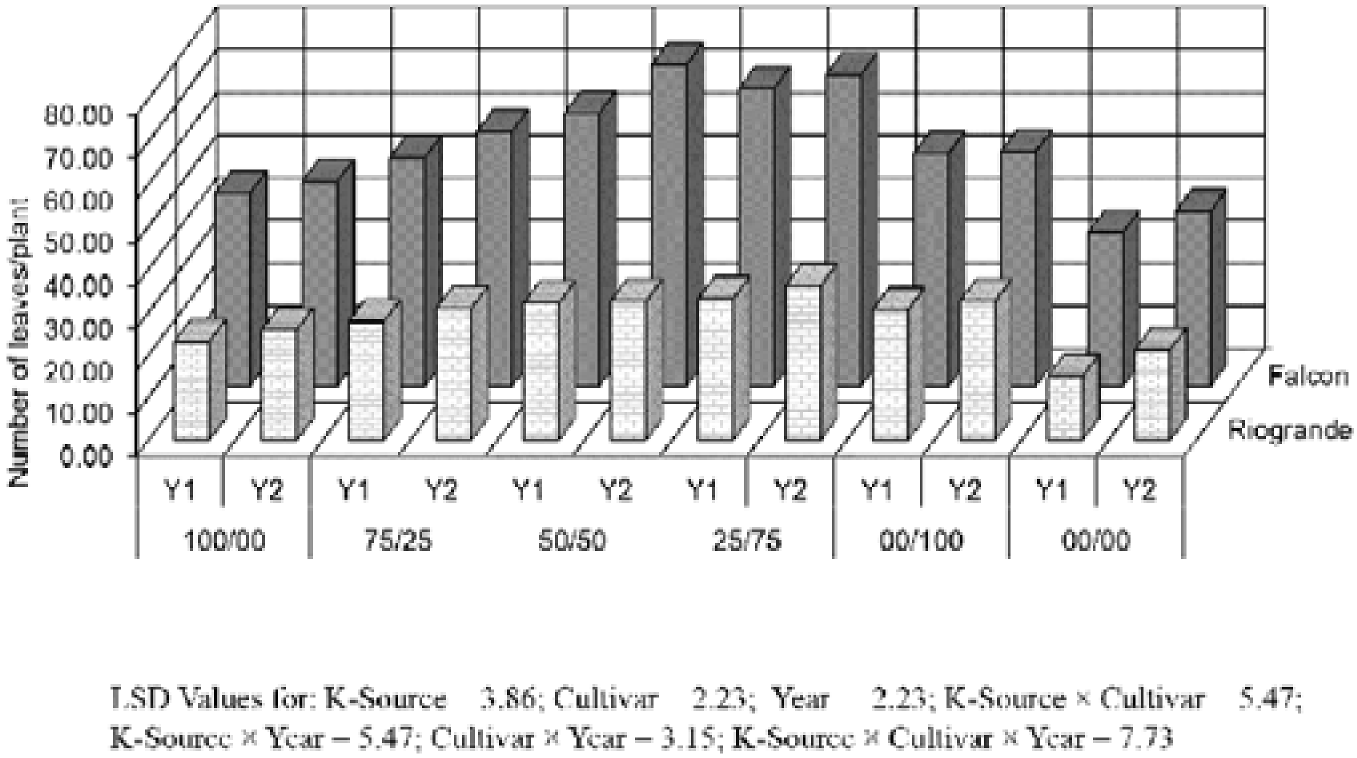


Figure 1. *Number of leaves plant $^{-1}$ as affected by the organic and inorganic potassium sources of tomato cultivars*

the pH was recorded with electronic pH meter.

Total soluble solid (°Brix)

Total Soluble Solids (TSS) of tomato fruit were recorded from each treatment with the help of Refractro-meter (Kernco, Instruments Co. Texas). The juice from tomato fruit were thoroughly mixed and drop of juice was placed on the slab of Refractro-meter and covered with a transparent led. The ^{0}Brix was observed through the eye piece of equipment.

Statistical analysis

The data calculated on different variables were subjected to analysis of variance (ANOVA) technique to observe the differences among the treatments and their interactions. In case of significant differences the means were separated using Least Significant Difference (LSD) test. Statistical computer software "Statistix 8.1" was used for computing the ANOVA and LSD (Jan et al., 2009).

Results and Discussion

Number of leaves plant^{-1}

The number of leaves plant^{-1} were significantly ($P≤0.05$) influenced by tomato cultivars, fertilizer treatments and years. The interaction between cultivars and fertilizer treatments was also significant ($P≤0.05$). Whereas, all the other interactions among cultivars, fertilizer treatments and years were non-significant regarding number of leaves plant^{-1}. The highest number of leaves (75.25) plant^{-1} was counted in cultivar Falcon with the application of potassium 50% each from PM and SOP during 2010. However the lower number of leaves plant $^{-1}$ (15) were counted in Rio Grande cultivar in control plants during 2009 (Figure 1).

The results showed that Falcon cultivar produced higher number of leaves plant^{-1} than Rio Grande. This could be attributed to plant genetic variability and root morphology that might have influenced the plant vegetative growth (Shahzad et al., 2007). The higher number of leaves produced by Falcon cultivar might also be due to the complementation of growth recessive alliles (Fu and Dooner, 2002) that changed the metabolic profile of the plant (Gartner et al., 2009). Whereas, the application of potassium from both sources increased number of leaves plant^{-1} that could be attributed to high proportion of easily available nutrients from chemical fertilizer to plant, while organic manure slowly decomposed and affected the plant vegetative growth at lateral stage. The addition of poultry manure with inorganic potassium source increased cation exchange capacity and might help in the uptake of potassium from the soil (Lin,

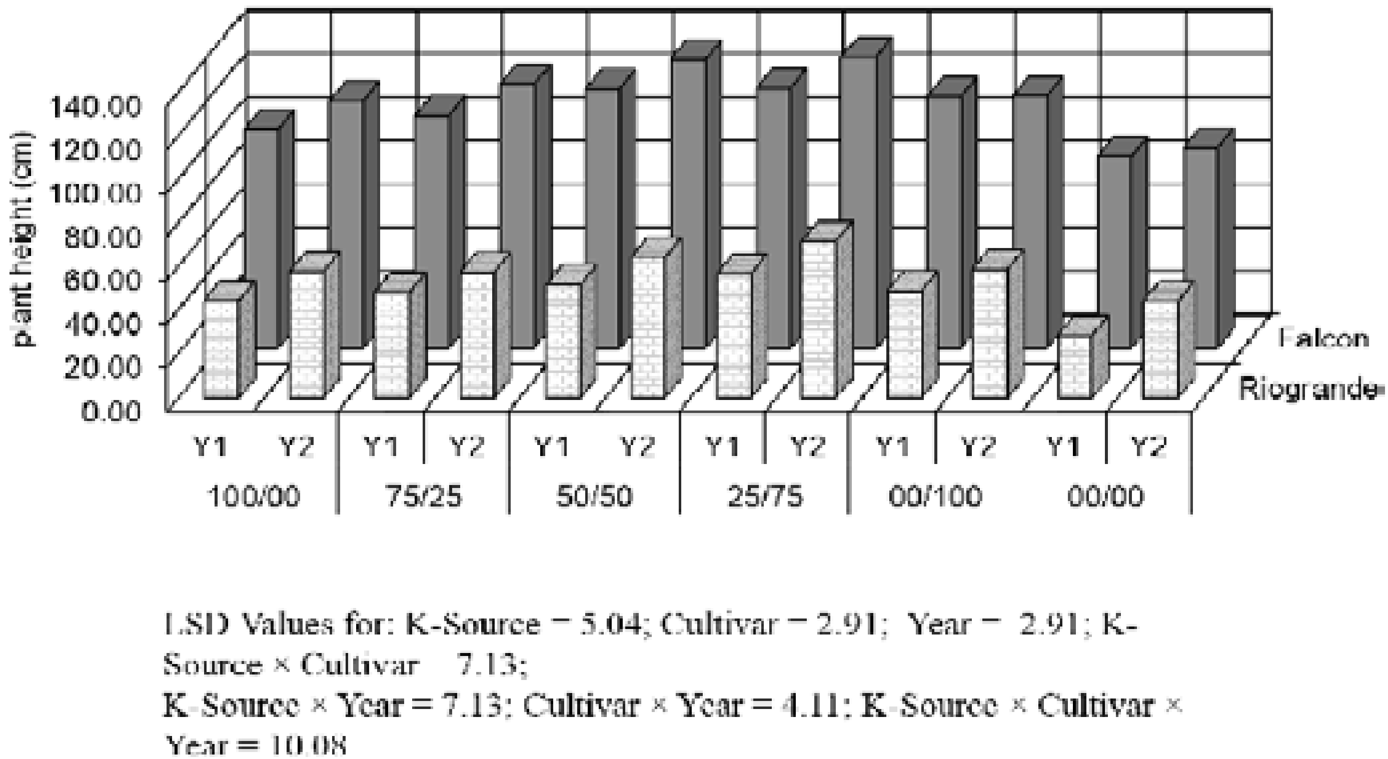


Figure 2. *Plant height as affected by the organic and inorganic potassium sources of tomato cultivars*

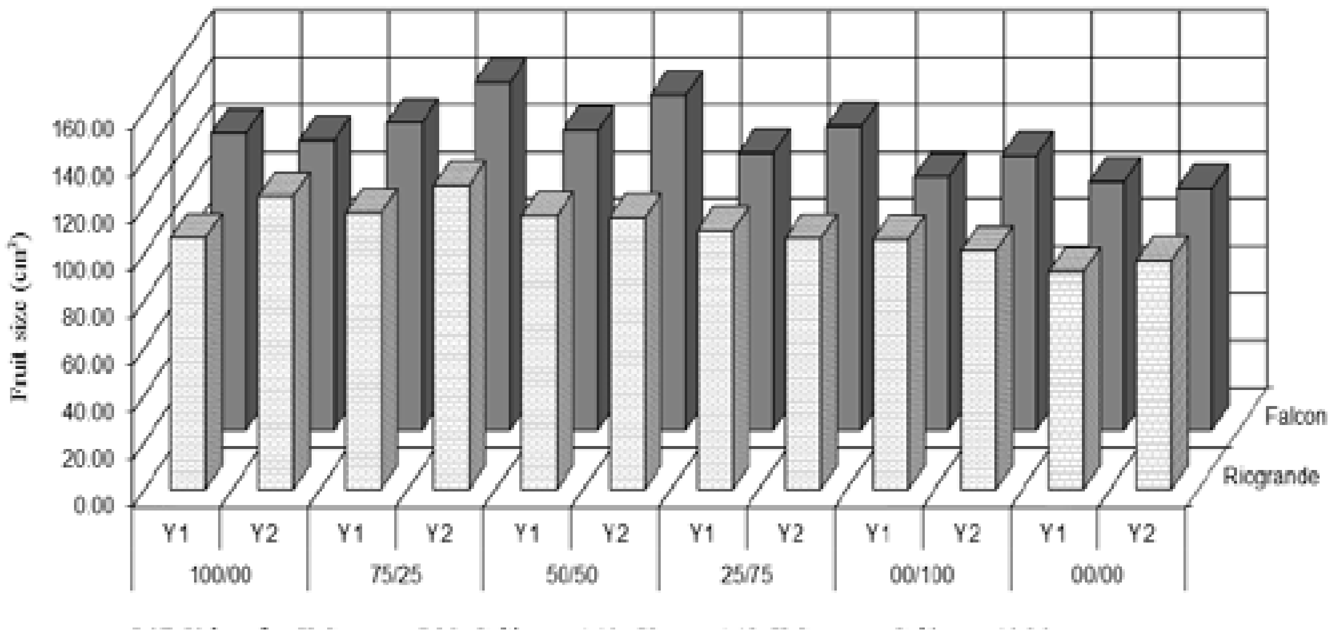


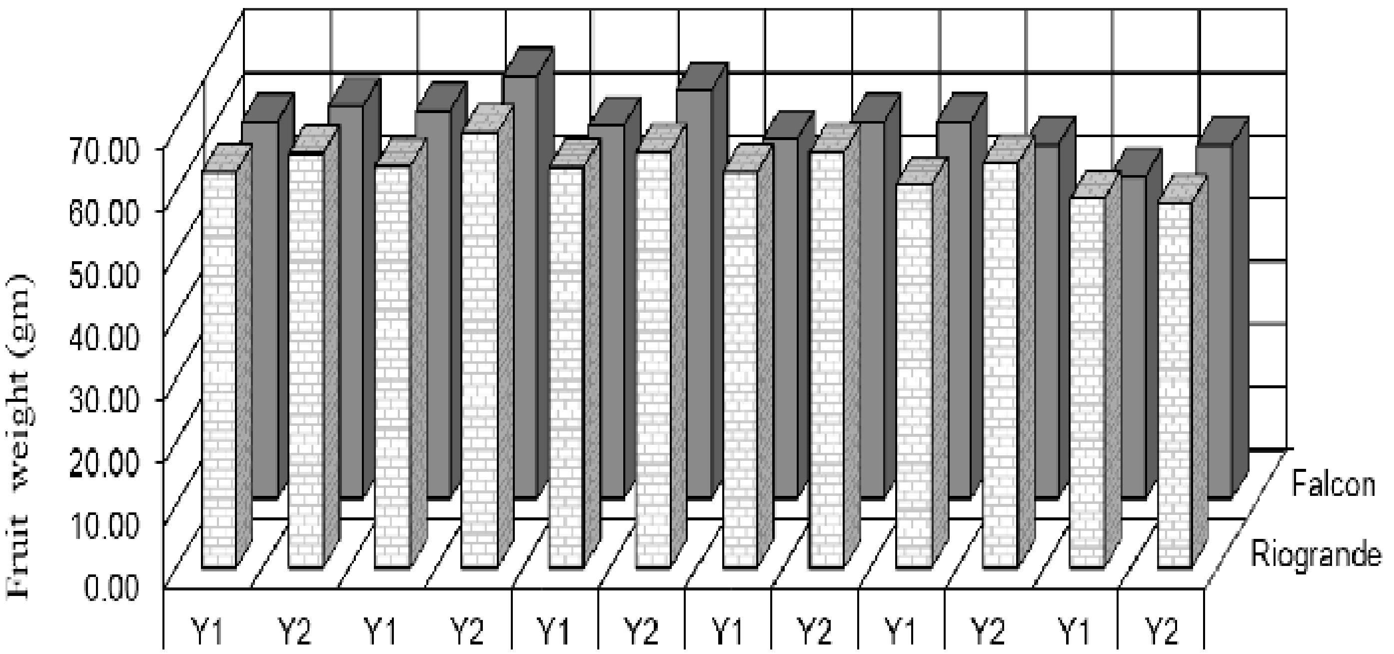
Figure 3. *Fruit size as affected by the organic and inorganic potassium sources of tomato cultivars*

2010). The year variation indicated that the increased in leaves plant^{-1} during 2010 might be due to favourable weather conditions for tomato plant growth. As water is an important constituent for the translocation of nutrients within soil and plant and enhanced decomposition of organic matter needed for microorganism to dissolved nutrients in soil and transported component from source to sink (Goluke, 1991).

Plant height (cm)

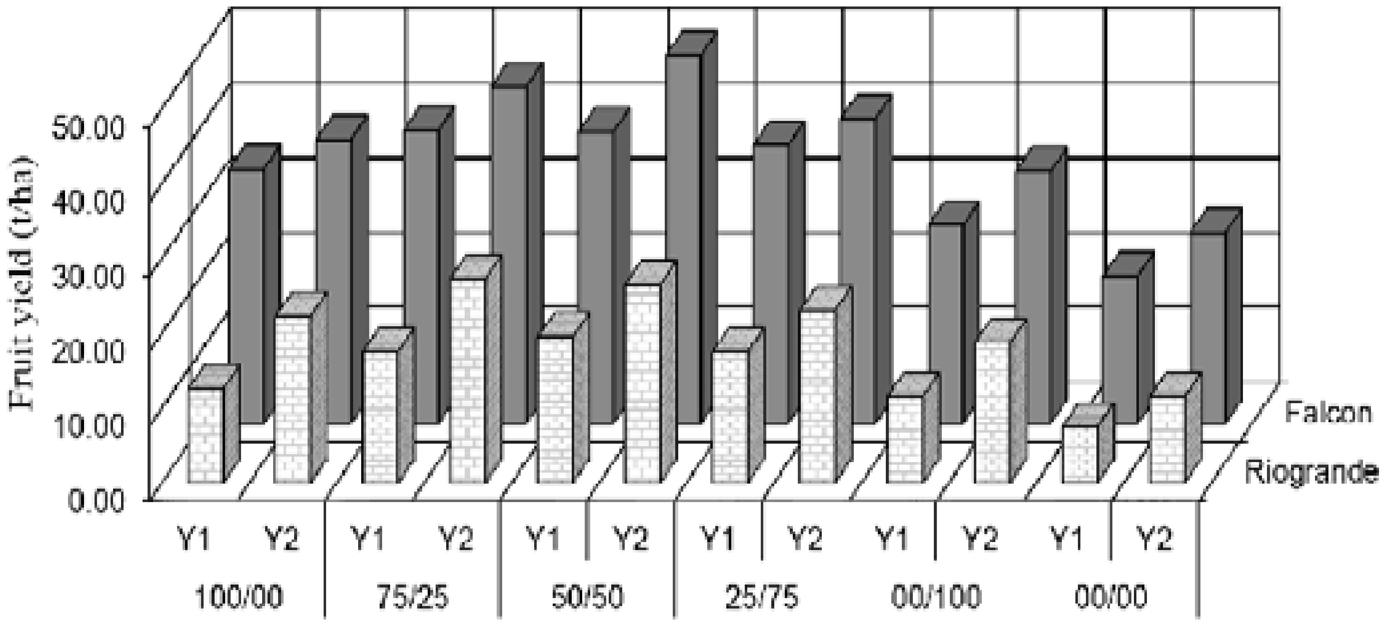
The tomato cultivars, fertilizer treatments and years significantly ($P \leq 0.05$) influenced the plant height. However, all the interactive responses among tomato cultivars, fertilizer treatments and year were non-significant regarding plant height.

Falcon cultivar resulted in taller plants (134 cm) with the application of 25-75% ration of PM and SOP re



LSD Values for: K-Source 3.12; Cultivar 1.80; Year 1.80; K-Source × Cultivar 4.41; K-Source × Year – 4.41; Cultivar × Year – 2.55; K-Source × Cultivar × Year – 6.25

Figure 4. *Fruit weight as affected by the organic and inorganic potassium sources of tomato cultivars*



LSD Values for: K-Source = 3.01; Cultivar = 1.74; Year = 1.74; K-Source × Cultivar – 4.26; K-Source × Year – 4.26; Cultivar × Year – 2.46; K-Source × Cultivar × Year – 6.03

Figure 5. *Fruit yield as affected by the organic and inorganic potassium sources of tomato cultivars*

corded in 2010 (Figure 2). While lower plant height (28.25 cm) was measured in Rio Grande cultivar during, 2010. This indicated that higher plant height of Falcon cultivar might be due to the genetic diversity of a genotype (Shahzad et al., 2007). The integrated nutrient management significantly increased plant height against unfertilized plants. The addition of manure released the nutrients more slowly and available to plant for longer time which eventually improved the root development and enhanced the crop yield

(Abou El Magd et al., 2005). The year variation indicated that the high precipitation recorded during, 2010 had positively affected the plant height as water is essential component in the nutrient absorption (Chartzoulakis et al., 1992).

Fruit size (cm^3)

The results regarding fruit size significantly (P≤0.05) varied between tomato cultivars, fertilizer treatments and years. However, none of the interactions among tomato cultivars, fertilizer treatments and years were significant.

The results (Figure 3) indicated that bigger fruit (147.10 cm^3) was observed in Falcon cultivar with the application of 75-25 ratio of PM and SOP during, 2010, closely followed by fruit size (141.70 cm^3) in Falcon with the application of potassium 50-50 ratio. Whereas, the smaller fruit (92.30 cm^3) was noted in Rio Grande in control during, 2009. The results pertaining to cultivars variation showed that Falcon produced bigger fruits than Rio Grande. The variation in fruit size might be due to genetic variability which was influenced by nutrient absorption capacity of plants that encouraged cell division and significantly affected fruit size (Mottaghian et al., 2008). Similarly potassium sources significantly affected the fruit size. The combine application of poultry manure and chemical source of potassium increased the nutrients uptake from soil and eventually increased the fruit size (Mottaghian et al., 2008). Furthermore, poultry manure enhanced the soil properties and soil fertility by increased moisture content and nutrients availability (Kaur et al., 2005) and this might have positive effect on fruit size. The year variation indicated that the favorable weather conditions and the high organic matter in 2010 might have leaded to bigger fruits (Lavee et al., 1990).

Fruit Weight (g)

Fruit weight was significantly (P≤0.05) different between tomato cultivars, fertilizer treatments and years. While all the interactions among cultivars, fertilizer treatments and years showed a non-significant variation regarding fruit weight.

The results (Figure 4) indicated that higher fruit weight (69.25 g) was noted in Rio Grande during, 2010 with the application of potassium 75-25 ratio of PM and SOP as compared to lower fruit weight (51.25 g) attained by Falcon in control treatment during, 2009. This showed that the difference in weight has highly correlated with fruit water content and a genetic variability (Proietti and Antognozzi, 1996). Whereas, the application of poultry manure increased the fruit weight of tomato crop by enhanced soil moisture and influenced the plant mass (Hepton, 2003). The application of adequate potassium increased fruit weight by increased translocation of photosynthates to fruits and water use efficiency (Ghourab et al., 2000). The year was also found as a source of variation regarding fruit weight during 2009 and 2010. This indicated that high organic matter and favourable weather conditions might have translocated high carbohydrates and increased water use efficiency increased fruit weight (Ghourab et al., 2000).

Yield ($t\ ha^{-1}$)

Yield was significantly (P≤0.05) influenced by tomato cultivars, fertilizer treatments and years. However, the interactions among cultivars, fertilizer treatments and years were non-significant.

The Falcon cultivar resulted in higher yield (49.25 $t\ ha^{-1}$) with the application of potassium source from PM and SOP at 50% each followed by fruit yield (45 $t\ ha^{-1}$) with application of 75-25 ratio of PM and SOP during, 2010 (Figure 5). However, lower fruit yield (7.50 $t\ ha^{-1}$) was recorded in Rio Grande in control during, 2009. The variation in fruit yield might be the higher genetic variability (Olaniyi and Fagbayide, 1999). Falcon cultivar might contain deep rooted system that efficiently utilized soil nutrients. Falcon also produced higher foliage than Rio Grande that might have positively affected the photosynthetic rate the main source of assimilates for fruits growth and development and eventually increased the tomato fruit yield (Schaffer et al., 1999). The addition of poultry manure to soil increased organic matter and nutrient availability by improved soil physical and chemical properties (Azeez et al., 2010) and these favorable condition might helped in higher yield. The yield variation in both years showed that the weather conditions significantly influenced the tomato production as water played essential role for the physiological activities of tomato and insufficient water at any stage adversely affected the yield and quality (Hanson et al., 2001).

Fruit pH

The mean data indicated that fruit pH was significantly (P≤0.05) varied between tomato cultivars and years. However, the fertilizer treatments showed a

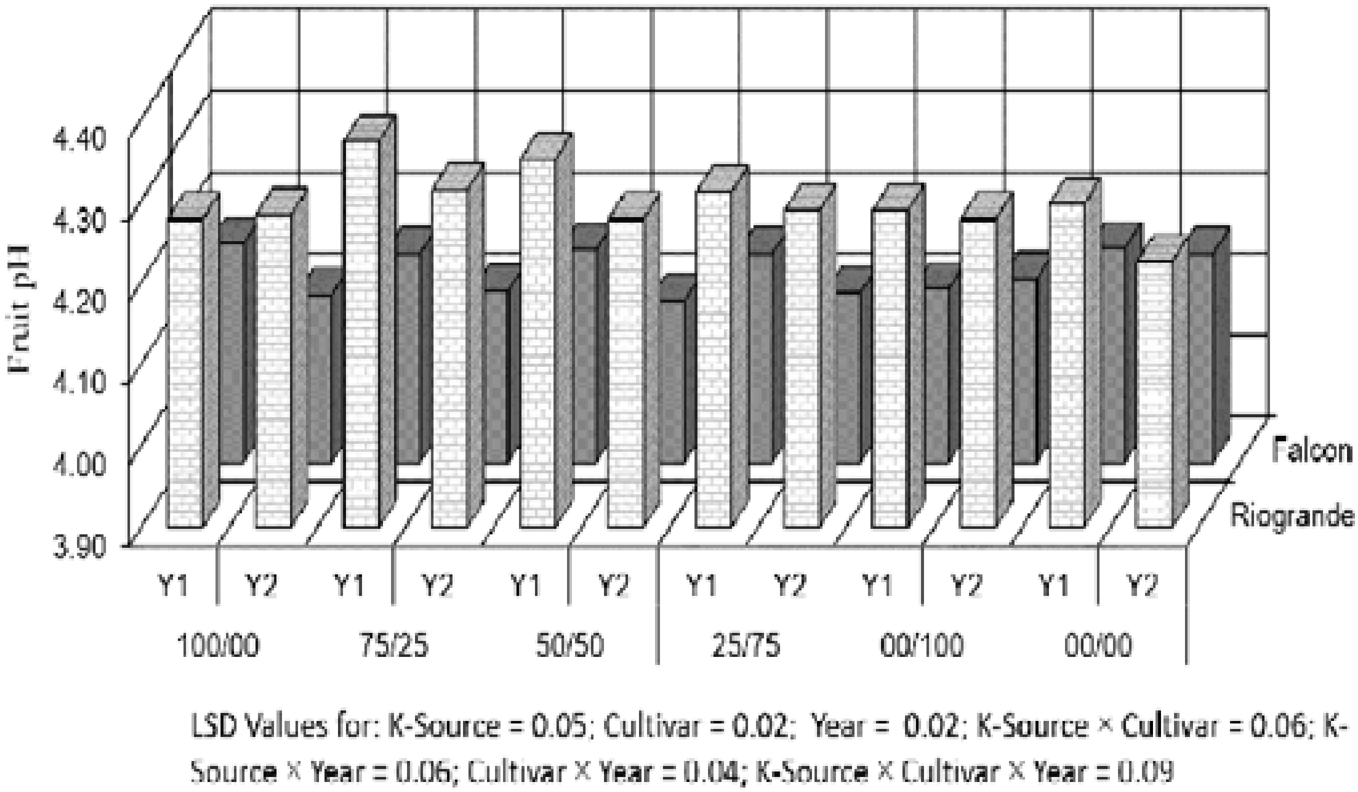


Figure 6. *Fruit pH as affected by the organic and inorganic potassium sources of tomato cultivars*

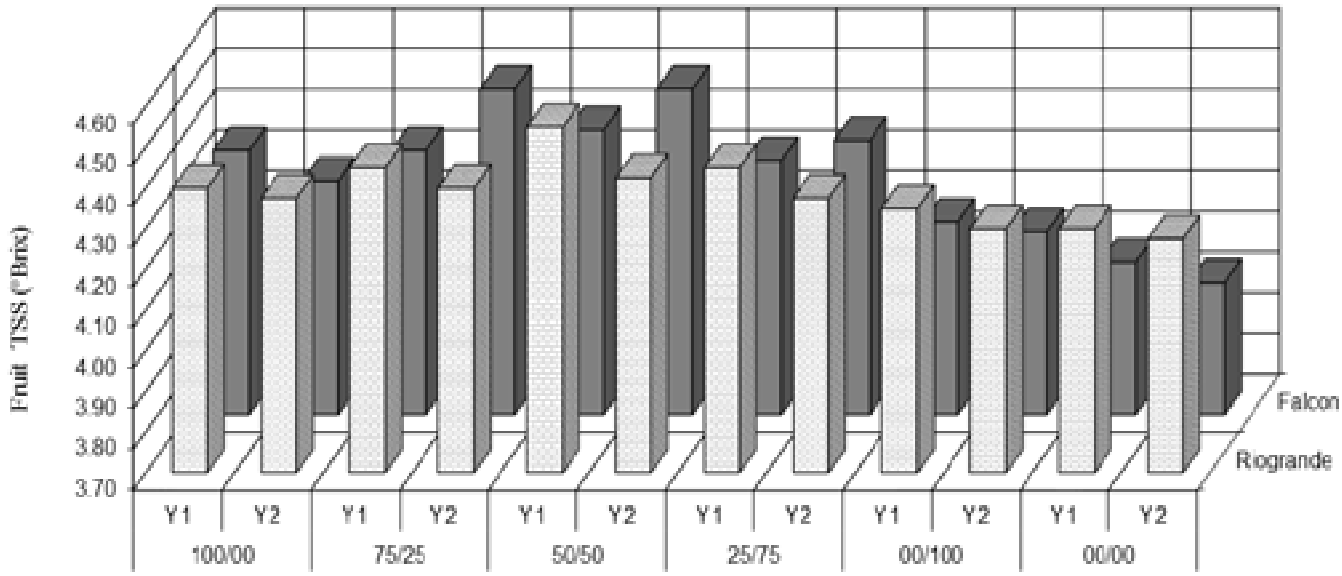


Figure 7. *TSS (°Brix) as affected by the organic and inorganic potassium sources of tomato cultivars*

non-significant variations regarding fruit pH. Similarly, all the interactions among cultivars, fertilizer treatments and years were non-significant.

The results in figure 6 indicated that higher fruit pH (4.37) was recorded in fruits of Rio Grande during. 2009, whereas, the lower fruit pH (4.10) was observed in fruits of Falcon during, 2009. The figures indicated that fertilizer treatments did not statistically influence the fruit pH. It was observed that Falcon contained lowered fruit juice pH as compared to Rio Grande. The difference in fruit juice pH might be the accumulation of malic and citric acid which was genetically controlled (Young et al., 1993). The fruit pH was higher during, 2009 as compared to fruit pH recorded during, 2010. According to Sanders et al. (1989) that

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fruit pH decreased as irrigation rates increased.

Total soluble solids (°Brix)

Tomato cultivars and fertilizer treatments significantly (P≤0.05) influenced Total Soluble Solids (TSS), while non-significantly influenced by year, similarly interactions among cultivars, fertilizer treatments and year.

It is revealed from figure 7 that higher TSS content (4.55 °Brix) was noted in fruits of Rio Grande with the use of K-source at 50% each from PM and SOP during, 2009. While, the lower TSS content (4.03 °Brix) was recorded in fruits of Falcon in control during, 2010. This indicated that the tomato cultivars significantly varied regarding TSS content. This variation in tomato cultivars might be the genetic variability due to absorbance of high nutrients from the soil. The lesser number of fruits produced by the cultivar Rio Grande might increase in TSS content due to higher assimilates from sink to source (Al-Lahlam et al., 2003). Similarly the combine application of poultry manure and Sulphate of Potash significantly increased TSS content in tomato cultivars. The higher organic manure increased the availability of potassium that played important role in the transportation of assimilates to fruits (Young et al., 1993). It was also reported that organically grown tomatoes contained higher total soluble solids compared to chemically fertilized crops (Lumpkin, 2005).

Conclusion and Recommendation

Cultivar Falcon produced significantly higher yield and yield components, whereas the Rio Grande cultivar resulted in higher TSS content of tomato fruit. The fertilizer application of organic and inorganic sources of potassium considerably increased the vegetative growth, yield and quality attributes of tomato fruit against control treatments. The application of higher ratio of K from chemical source increased the vegetative growth. By contrast when the K was derived from poultry manure, it increased the yield and quality of tomato fruit. Among the combination treatments, the application of organic and inorganic sources at equal ratios significantly encouraged the fruit yield, while increasing the ratios of poultry manure enhanced the fruit quality attributes. Therefore, Falcon cultivar is recommended for general cultivation in the study area, whereas the combined application of 50-50 ratio each from poultry manure and chemical source of K was recommended for higher yield.

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