Potential role of potassium sources, its time of application and tree canopy orientations in regulation of sex expression and yield attributes of sweet lime

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Abstract

Shy bearing tendency is one of the serious problem in the commercial production of sweet lime. The shy bearing tendency of sweet lime is mainly due to the production of small number of perfect flowers. Potassium is known to play critical role in perfect flowers formation and other fruit attributes. Therefore the current study was conducted during 2019 to study the potential role of potassium sources (Control, Potassium chloride (KCl), Potassium sulfate (K_2SO_4), Potassium nitrate (KNO_3) its time of application (15^{th} Feb, 25^{th} Feb, 7^{th} March and 17^{th} March) and tree canopy orientations (North, South, West and East) in regulations of sex expression and yield attributes of sweet lime. Results indicated that potassium nitrate significantly increased perfect flowers (27.34 %), fruit set (69.14 %) and decreased staminate flowers. Potassium chloride application resulted in least fruit drop (37.44 %). In case of time of application, 17^{th} March application resulted in increased perfect flowers (26.74 %), least staminate flowers (72.60 %) and reduced fruit drop (36.75). Results regarding tree canopy orientations indicated that best results were recorded from Northern direction of the canopy in term of maximum perfect flowers (25.30 %), fruit set (67.91 %) and least staminate flowers (74.40 %). Least fruit drop (36.90) was noted from Southern direction. It is concluded that potassium nitrate as a source of potassium may be sprayed on 17^{th} March for more desirable results of sweet lime.

Keywords: Potassium sources, Time of application, Tree canopy orientations, sex expression, yield attributes

Introduction

Sweet lime (*citrus limmeta*) is one of the important member of Rutaceae family which commonly consumed for its refreshing juice. When fully ripe the size of sweet lime is comparable to large lemon and are green or more commonly yellow in color. The taste lack acidity which causes tartness. The flavor of the fruit is mild and is refreshing which is used particularly for juice

extraction but may be also eaten fresh from the tree. Like other citrus fruits sweet lime also contain fair amount of vitamin C and folic acid which plays important role in immunity, glowing skin and support bones and joints (Kumar *et al*., 2020).

Potassium is an important plant nutrients that effects plant growth and development. This cation is most abundant in plants (Wang *et al*., 2013). Potassium is not found in any organic compound (Clarkson and Cooke, 2012.). Potassium is involved in all most every growth and developmental process of plant and has many functions (Popova and Golldack, 2007). Potash plays vital role in transport of photosynthate, stomatal regulation and carbohydrates synthesis (Lester *et al*., 2005), and is directly related to cell osmotic potential to minimize different stress responses (Camkak *et al*., 1995). Many investigations has reported that potassium plays important role in flower induction. The KNO_3 treatment has been successfully used for flower induction in mango, for advancement of flowering and fruiting and to break biennial bearing habit of trees (Kumar *et al*., 2017). Source of fertilizers effects the crop productivity differently as it contains different nutrient with the main nutrient. Most common sources of potash available in market includes, Murate of potash (MOP) approximately 60 % K , sulfate of potash (SOP) approximately 50 % K, potassium nitrate (KNO_3) approximately 44 % K, potassium thiousulfate ($K_2S_2O_3$) approximately 17 % K. Different studies conducted earlier have demonstrated different effects with different source on yield, quality and post harvest attributes. Foliar application of an appropriate source of potassium can significantly increase yield, Improve quality and during cold storage it can alleviate chilling injury (Mshraky *et al*., 2016). Keeping in view the importance of Potassium and its sources the current study was designed to study the influence of potassium sources and its time of application on various parameters of sweet lime.

Materials and Methods

An experiment "Potential role of potassium sources, its time of application and tree canopy orientations in regulation of sex expression and yield attributes of sweet lime" was conducted in private research farm at Rustam, Mardan, Pakistan during 2019. Trees of uniform size and age were selected. Different Potassium sources (Potassium chloride (KCl), Potassium sulfate (K_2SO_4) and Potassium Nitrate (KNO_3), time of application (15^{th} Feb, 25^{th} Feb, 7^{th} March and 17^{th} March) and tree canopy orientations (North, South, West and East) were the three factors which were studied during the research. The experiment was carried out RCBD split-split plot arrangement.

All the treatments were replicated three times. Required concentration of potassium which was 1.5 % was determined in each source according to its molecular weight and was sprayed as a foliar spray.

Results and Discussion

Perfect flowers (%)

Statistical analysis showed significant results regarding perfect flowers in response of potassium sources, time of application and tree canopy orientations, while interactions were non significant (Table 1). Potassium sources had a positive effect in increasing perfect flowers, where KNO_3 application had the highest percentage of perfect flowers (27.34 %), followed by KCl with 23.42 % perfect flowers, while least perfect flowers (15.47 %) were noted from control treatment which was followed by K_2SO_4 with 19.09 % perfect flowers. Time of application increased perfect flowers in ascending order from dormant stages towards active stage, where maximum perfect flowers (26.74 %) were produced with 17th March application, followed by 7th March with 24.49 % perfect flowers, while least perfect flowers (15. 10 %) were noted when trees were treated on 15th Feb, followed by 25th Feb with 18.96 % perfect flowers. In case of tree canopy orientations, Northern direction of canopy produced more perfect flowers (25.30 %), followed by Eastern direction (21. 61 %), while minimum (18.10 %) were noted on Southern side of the canopy which was statistically at par with western side of the canopy with 20.31% perfect flowers.

Staminate flowers (%)

Statistically analyzed data showed that potassium sources, time of application and tree canopy orientations had significant effect on staminate flowers, while the interactions were non significant (Table 1). Least staminate flowers (72.03 %) were noted with the application of KNO_3, followed by KCl (76.57 %), while control treatment had maximum staminate flowers (84.31 %), which was followed by K_2SO_4 with 80.90 % staminate flowers. Potassium application practiced on 17th March had minimum staminate flowers (72.60 %), followed by 7th March (75.51 %), while maximum (84.89 %) were noted with application practiced on 15th Feb which was followed by 25th Feb with 80.82 % staminate flowers. In case of tree canopy orientations, Northern position produced least

staminate flowers (74.70 %), followed by East (77.76 %), while the highest (81.69 %) were noted on Southern position that was statistically at par with western side with 79.68 % staminate flowers.

Perfect flowers are very much important as it is directly related with yield. Sex expression in different plants is influenced by Nutrition, light and temperature (Heslop-Harrison, 1957). Different authors have reported that potassium nitrate significantly effected sex expression of different plants (Sing *et al*., 2019; Muhammad *et al*., 2007). Among different sources, potassium nitrate significantly increased hermaphrodite flowers. Potassium facilitate opening and closing of stomata which favors enough carbon dioxide supply. Potassium also improve water use efficiency and sugar which is required for maintenance and for normal plant growth. Moreover potassium facilitates translocation of sugars from source towards sink (Zekri and Obreza, 2013). Perfect flowers need more carbohydrates for the requirement of additional structures and for fertilization as compare to staminate flowers (Srividhya and Kennedy, 2019), as potassium promotes photosynthesis so more hermaphrodite flowers will be produced. Potassium nitrate significantly increased perfect flowers because it also contains nitrogen which plays important role in flowering (Yeshitela *et al*., 2003). Nitrate and nitrogen have been reported to regulate flowering in various species (Lin and Tsay, 2017). Potassium nitrate was followed by KCl in increasing perfect flowers this could be due to the positive role of chlorine in photosynthesis (Chen *et al*., 2010). Different chemicals including potassium nitrate resulted in minimum sex ratio due to ethylene production which in turn resulted in maximum hermaphrodite flowers. Similar results were found by Quijada *et al*. (2009) who reported that hermaphrodite flowers were significantly increased by Potassium nitrate as compare to other chemicals. Similar results were also reported by Kumar and Reddy (2008), Sing *et al*. (2019) in mango. Staminate flowers were significantly reduced by potassium nitrate as compare to other sources of potassium, this may be due to the fact that potassium nitrate favor hermaphrodite flowers due to its role in photosynthesis and assimilate transport. When Nitrogen was combine with other nutrients such as phosphorous and potash it significantly reduced staminate flowers (Omini and Hossain, 1987). Potash stimulate ethylene which in turn promote hermaphrodite flowers and reduce staminate flowers (Sing *et al*., 2019). Similar findings were also reported by Yeshitela *et al*. (2003) and Kumar *et al*. (2017) in mango. The highest percentage of perfect flowers and least staminate flowers were noted when potassium was applied on 17th March. Fertilizers produce most desirable results when applied on its proper time and proper phenological

stage (Lovatt, 2013), this must be the most appropriate timing for foliar potash application to effect sex expression. In case of tree canopy orientations, increased perfect flowers and least percentage of staminate flowers were recorded on North direction of the canopy. As the Northern side receive less intense light as compare to other canopy directions so it remains un effected by the damaging effect of light and hence this may the possible reason for the highest hermaphrodite flowers production. Under very high light intensity leaves intercept large amount of photons which result in photorespiration and inhibition (Asada, 1999) affecting the net photosynthate production and damaging photosynthesis apparatus (Hamadziripi, 2012). High temperature can also cause significant damage to the plant by production of reactive oxygen species (Foyer *et al*., 1994). These are dangerous to the plants cells by effecting phospholipid membranes, proteins and nucleic acids (Alscher *et al*., 1997), hence these damaging effects can significantly affect photosynthesis and so hermaphrodite flower production on more exposed position of tree canopy. Increase in hermaphrodite flowers on Northern side was also reported by Majumdar and Mukherjee (1961) in mango and Ibrahim *et al*. (2011) in sweet orange.

Fruit set (%)

Statistical analysis showed significant results regarding the effect of potassium sources and tree canopy orientations, whereas time of application was non significant. In interactions time of application x tree canopy orientations was significant, while rest were non significant (Table 1). Potassium sources showed positive effect on fruit set percentage where highest fruit set (69.14 %) was noted with KNO_3 application which was statistically at par with K_2SO_4 and KCl with 63.89 % and 62.92 % fruit set respectively, while minimum (51.79 %) was noted from control treatment. In tree canopy orientations, maximum fruit set (67.91 %) was produced on Northern side of the tree canopy, followed by Eastern side of the canopy with 63.19 % fruit set, while least (55.86 %) was on Southern side of the canopy, followed by Western side with 60.76 % fruit set. Interaction between time of application and tree canopy orientations, showed that 17th March application increased fruit set on different tree canopy orientations except south direction which had maximum fruit set on 7th March and was declined on 17th March application. The highest fruit set (77.20 %) was noted on Eastern direction of the tree when trees were treated on 17th March, while

least fruit set (44.28 %) was produced on Southern sides when foliar application was done on 15th Feb (Fig i).

Sufficient nutrients are required for plants early in the growth cycle to provide essential components required in flower bud formation and in fertilization of flower. Due to the high usage of nutrients earlier in bud development and vegetative growth the nutrients get decreased in plant tissues (Keller, 2015). In such condition nutrients like potassium are not provided enough due to its slow movement from soil to plant tissues, therefore these conditions are considered important factor in limiting flowering and fruit set of a crop (Bonomelli and Ruiz, 2010). Plant growth and metabolism require the translocation of carbohydrates from photosynthetically active tissues into sink organs such as roots, flowers and seeds, potassium plays important role in this phenomenon (Tranknera *et al*., 2018). Potassium can improve the effect of transferring other nutrients and can do better loading of photosynthate during flowering, fertilization and fruit set (Mengel, 2007; Keller, 2015). Zekri and obreza, (2013) stated that potassium is required for fruit formation and for enhancement of other quality parameters like size, color and flavor. Similar results were found by Yeshitela *et al*. (2013) who published that Nitrogen supplement from KNO_3 might be the reason for improvement in yield parameters because trees needs to have enough nitrogen reserve for subsequent flowering and fruit formation. Nitrogen is also essential for the absorption of other nutrients and are particularly important during flowering and fruit set (Neto *et al*., 2008). The highest fruit set percentage with potassium nitrate were also noted by Oostiluyse (1996), Sergent *et al*. (1997), Machado and Sao Jose, (2000) and Debnath and Kundu, (2001). Maximum fruit set was noted when potash was applied on 17th March, this could be related with better translocation of sugars to sink on this stage. Improvement in fruit set when potash was applied on different phenological stages were also reported by Lovatt, (1999) and El-Tanany *et al*. (2011). In case of tree canopy orientations, increased fruit set was noted on North side of the canopy, this might be due to the availability of more carbohydrates to the sink on this direction. High radiations can severely damage the ability of plant to perform photosynthesis (Casanova-Gascon *et al*., 2019) by production of reactive oxygen species (Foyer *et al*., 1994). Northern side receive less radiation as compare to other directions and are safe from the damaging effects of radiation hence the fruit set may have improved. Similar results were reported by Ibrahim *et al*. (2011) who reported that

during high temperature in the noon the eastern side become in shade, while northern side are completely safe from damaging effect of high light intensity which result in improved fruit set.

Fruit drop (%)

Data regarding fruit drop percentage showed that potassium sources, time of application and tree canopy orientations significantly affected fruit drop percentage, while all interactions were non significant (Table 1). Potassium sources played vital role in reduction of fruit drop where least fruits (37.44 %) were dropped with the application of KCl, followed by KNO_3 (42.20 %), while more fruits (53.35 %) were dropped from untreated trees. Time of application reduce fruit drop in descending order from Feb to March application, where minimum fruit drop (39.62 %) was noted on 17th March application which was followed by 7th March with 42.45 % fruit drop, while the highest (51.49 %) was noted on 15th Feb application which was statistically at par with 25th Feb with 45.99 % fruit drop. Tree canopy orientations showed different results regarding fruit drop percentage, where least fruits (36.90 %) were dropped from the Southern side of the canopy, while Northern side had maximum fruit drop (48.75 %) that was statistically at par with Eastern and western side with 47.65 % and 46.20 % fruit drop respectively.

Potash is essential macro nutrients that plays important role in yield enhancement of different crops. K deficiency may lead to poor yield and quality of citrus fruits and also increase fruit drop (Amina *et al*., 2018). Potassium application mainly enhance the uptake of other nutrients which then contribute to the enzymes which help in the translocation of sugars to the growing sinks and increases yield and yield components. The role of potassium in various physiological processes particularly enzymes activation and assimilate transport to developing sink could be the possible reasons responsible for reduction in fruit drop. In case of time of application, the least fruit drop was noted when potassium was applied on 17th March, this might be due to more carbohydrates production and translocation of sugars to developing sink due to improved vegetative growth on this stage. Lovatt, (1999) reported that foliar fertilization should be done on its proper time to fulfill the demand of the plant and to get the desirable results. In canopy orientations, least fruit drop was noted at South direction this may be related with less number of hermaphrodite flowers production and less fruit set on this direction which resulted in minimum fruit drop. Contrast results were

reported by Ibrahim *et al*. (2011) who reported the highest fruit drop from Southern direction of tree canopy.

Table 1: Perfect flowers (%), staminate flowers (%), fruit set (%) and fruit drop (%) of sweet lime as affected by Potassium sources, time of applications and tree canopy orientations

Sources of Potassium (S)	Parameters			
	Perfect flowers (%)	Staminate flowers (%)	Fruit set (%)	Fruit drop (%)
Control	15.47 c	84.31 a	51.79 b	53.35 a
KCl	23.42 ab	76.57 bc	62.92 a	37.44 c
K_2SO_4	19.09 bc	80.90 ab	63.89 a	46.51 b
KNO_3	27.34 a	72.03 c	69.14 a	42.20 bc
LSD (P≤0.05)	5.680	5.692	8.378	5.536
Time of application (TA)				
15th Feb	15.10 c	84.89 a	53.73	51.49 a
25th Feb	18.96 bc	80.82 ab	60.79	45.99 ab
7th March	24.49 ab	75.51bc	64.69	42.45 b
17th March	26.77 a	72.60 c	68.52	36.75 b
LSD (P≤0.05)	7.595	7.931	NS	7.473
Tree canopy orientations (CO)				
North	25.30 a	74.70 b	67.91 a	48.75 a
South	18.10 b	81.69 a	55.86 c	36.90 b
East	21.61 ab	77.76 ab	63.19 ab	47.66 a
West	20.31 b	79.68 a	60.76 bc	46.20 a
LSD (P≤0.05)	4.653	4.725	6.592	5.610
Interactions (LSD at P≤0.05)				
S x TA	--	--	--	--
Significance	NS	NS	NS	NS
S x CO	--	--	--	--
Significance	NS	NS	NS	NS
TA x CO	--	--	Fig. i	--
Significance	NS	NS	*	NS
S x TA x CO	--	--	--	--
Significance	NS	NS	NS	NS

Means with same letters in column are statistically not different at 5 % level of significance.
NS. = Non-significant and * = Significant at P≤0.05.
KCl = Potassium chloride, K_2SO_4 = Potassium Sulfate, KNO_3 = Potassium nitrate

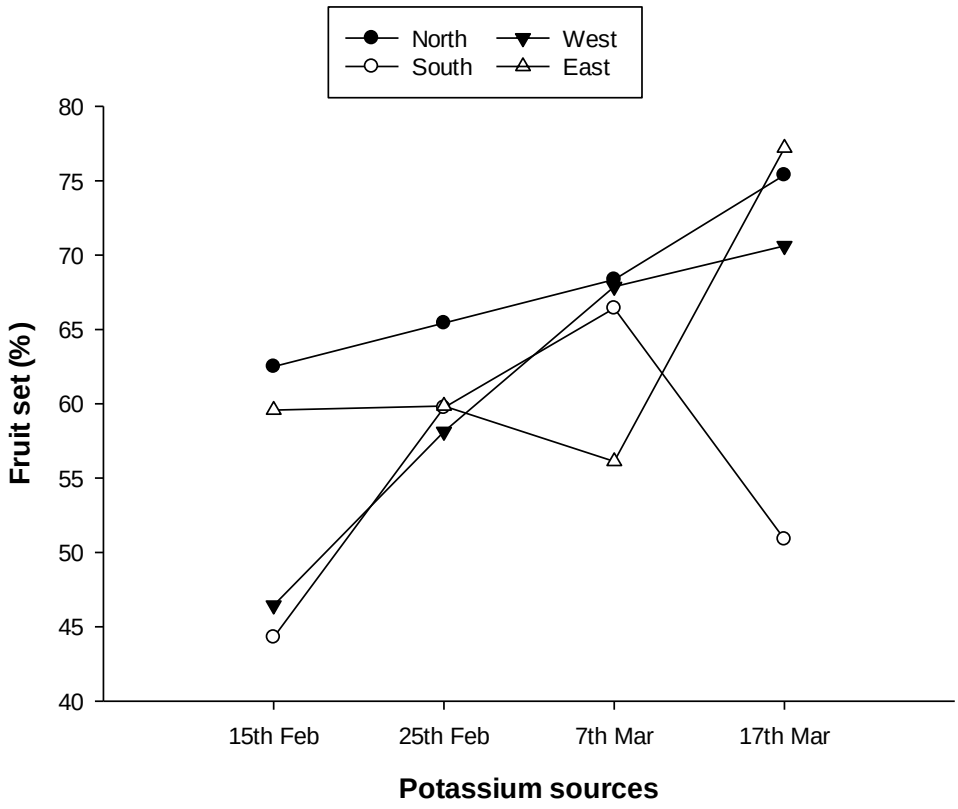

Fig i. Influence of tree canopy orientations and time of application on fruit set (%).

Conclusion

It has been concluded from the current research that potassium sources, time of application and tree canopy orientation had significant effect of various flowering and fruiting parameters of sweet lime. Potassium nitrate and 17th March application in particular produced best results. In the future potassium nitrate can be effectively used for perfect flowers and fruit production in various andromonoecious species. It has also been concluded that in future tree canopy can be modified to get more desirable results.

Recommendations

It has been recommended that potassium nitrate as a source of potassium may be sprayed on 17th March or 8 days before flowering at agro climatic conditions of Mardan, Pakistan for more desirable results of sweet lime.

Conflict of interest

The authors declare that they have no conflict of interest.

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