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Impact of foliar applied Ethrel, potassic compounds and thiourea on flowering and fruiting attributes of Litchi (*Litchi chinensis* Sonn.)

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Abstract
Plant growth regulators and nutrients play a significant role in altering plant growth subsequently yield and quality. The impact of foliar application of ethrel, potassic compounds [Potassium nitrate (KNO_3), Potassium dihydrogen phosphate (KH_2PO_4) and Dipotassium hydrogen phosphate (K_2HPO_4)] and thiourea on flowering and fruiting characteristics of Litchi (*Litchi chinensis* Sonn.) was explored in an experiment based on a randomized block design with thirteen treatments and three replication at HRC, GBPUA&T Pantnagar (India). The treatments included T_1 [ethrel (400 ppm)], T_2 [KNO_3 (1%)], T_3 [K_2HPO_4 (1%)], T_4 [KH_2PO_4 (1%)], T_5 [thiourea (1%)], T_6 [K_2HPO_4 (2%)], T_7 [KH_2PO_4 (2%)], T_8 [K_2HPO_4 (1%) + KNO_3 (1%)], T_9 [KH_2PO_4 (1%) + KNO_3 (1%], T_{10} [K_2HPO_4 (1%) + thiourea (0.5%)], T_{11} [KH_2PO_4 (1%) + thiourea (0.5%)], T_{12} [KNO_3 (1%) + thiourea (0.5%)] and T_{13} as control. The foliar spray of these chemicals was done thrice from end of September to November at 20 days interval. Early panicle initiation, advancement in flowering (3 days), maximum number of female (324.63) and total flowers (836.39), highest fruit set per panicle (59.49), minimum fruit drop (75.90%) and highest yield (43. 82 kg/tree) was observed in treatment T_2 [KNO_3 (1%)] whereas, highest fruit weight (20.99g) and aril weight (17.30g) was observed in T_1 [ethrel (400 ppm)] treatment. Maximum flowering intensity and highest pulp recovery was reported in T_9 [KH_2PO_4 (1%) + KNO_3 (1%] and T_4 [KH_2PO_4 (1%)] treatments, respectively.

Keywords: *Litchi chinensis*, ethrel, potassium, flowering, fruiting, yield

Introduction
Litchi (*Litchi chinensis* Sonn.) is one of the most important subtropical fruit grown throughout the world for its juicy fleshy aril. It is believed to have originated in Southern China and Northern Vietnam region from where it became widely distributed in the Subtropics (Menzal and Simpson, 1986) [23, 25]. Litchi was introduced to India by the end of the 17th century (Liang, 1981) [20]. India is the second largest litchi producer in the world next to China and has substantially expanded its cultivation in past 50 years. The annual production of litchi in India accounts to 6.86 lakh MT from an area of 0.92 lakh hectare with an average productivity of 7.4 MT/ha (Anonymous, 2018) [3]. Litchi is an excellent source of vitamin C (40 mg/100g) and contains significant amount of protein (0.8-0.9%), fat (0.3%), pectin (0.43%) and mineral content especially calcium, phosphorus and iron (Pandey and Sharma, 1998) [29]. It is among one of the few fruit crops, which is exact to its climatic requirement. Litchi flourishes well in moist subtropical regions with abundant rainfall. Dry winds during summer and frost in winter are detrimental for its growth. Its cultivation is restricted to lower tropics and subtropics where flowering and fruiting is uneven due to lack of prerequisite cool temperature (Hegele *et al*., 2010) [12]. Irregular flowering in litchi trees during spring season is associated with previous years vegetative flushing in late autumn and early winter which can result in inconsistent yields (Nagao *et al*., 2000) [27]. Among other problems associated with the production of litchi, the narrow genetic base of litchi results in the availability of litchi for a very short period of time in the market, which is further reduced due to poor shelf life and browning of litchi fruits. The initial fruit set in litchi is very high but a small proportion of fruits finally mature due to

cracking and fruit drop. Chemicals and PGR's play a significant role in altering the plant response from vegetative to reproductive stage in litchi. Foliar application of plant nutrients is helpful in satisfying plant requirements and can be highly effective when nutrient uptake via the root system is limited. Potassium is essential nutrient for numerous physiological and biochemical processes like photosynthesis, phosphorylation, transportation of photo assimilates, enzyme activation, transpiration, stress tolerance (Pettigrew, 2008) [30]. Foliar application of potassium to bearing fruit trees increases fruit size, soluble solids, ascorbic acid, colour, shelf life, and shipping quality (Lester *et al*. 2007) [19]. Potassic compounds like potassium nitrate (KNO_3) can be used for dormancy breaking in buds (Trewavas, 1983) [40]. Several researchers have confirmed the role of potassic compounds in enhancing flowering in different fruit crops. Valmayor (1962) [42] reported increased internal ethylene concentrations in shoots as well as ethylene forming enzyme (EFE) activity in leaves by KNO_3, which induced flowering. KNO_3 enhances flowering especially in tropical regions where cold temperature for floral induction may not be sufficient (Oosthuyse, 1992). In subtropical regions where winter conditions are usually sufficient for floral induction, flowering enhancement by KNO_3 has not been reported. Protacio (2000) [31] hypothesized increase in starch concentration and subsequently floral stimulus in the shoots when the gibberellins levels fall below a threshold level. However, the buds remain quiescent even after sufficient starch accumulation until conditions are favourable for flowering. KNO_3 activates those quiescent buds for floral initiation. Srihari and Rao (1998) [37] reported induced flowering on axillary shoots and increased yield of fruit trees by foliar application of Orthophosphoric acid. Garad *et al*. (2013) [9] reported increased number of flower percentage, maximum fruits per panicle and maximum cost benefit ratio in mango by spraying KH_2PO_4 (1%) + KNO_3 (1%). Ethylene ($H_2C=CH_2$) is a simplest olefin that exists in gaseous phase under normal physiological conditions. It is produced from all parts of plants and plays an important role in cellular, developmental and stress related processes in plants. Ethrel or Ethephon (2-chloroethyl phosphonic acid) which is a synthetic plant growth regulator undergoes chemical biodegradation at pH greater than 4.1 in cell cytoplasm to release ethylene (Urwiler and Stutte, 1986; Kasele *et al*., 1995) [41, 15]. Foliar application of ethrel has been found to increase C/N ratio in shoots and leaves, highest number of flowering panicles and maximum fruits at initial stage and also at final stage in Litchi Cv. Bombai (Mandal *et al*., 2014) [21]. Thus, well balanced plant nutrition management is essential for maximum yield and fruit quality. Keeping in view the above factors under consideration, the present experiment was conducted to evaluate the effect of different chemicals on flowering and fruiting attributes of litchi cv. Rose Scented.

Material and Methods

The present experiment was conducted at Horticultural Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar on 15 years old litchi trees of Cv. Rose Scented planted at 10×10m planting distance. The centre is located at 29^0N latitude, 79.3^0E longitudes and 244 m above mean sea level. The region is characterized by humid subtropical climate with dry summers and cold winters. Maximum temperature ranges from 30^0 C to 43^0 C in summers and 5^0 C to 10^0 C in winters along with mean rainfall 1400 mm per annum. Monsoon rains occurs from the third week of June to middle of September. Frost can be expected from the last week of December to first week of February. The soil of the experimental site was silty clay loam under the order mollisols. The experiment was laid out in randomized block design with 13 treatments and 3 replications. The treatments T_1 [ethrel (400 ppm)], T_2 [KNO_3 (1%)], T_3 [K_2HPO_4 (1%)], T_4 [KH_2PO_4 (1%)], T_5 [thiourea (1%)], T_6 [K_2HPO_4 (2%)], T_7 [KH_2PO_4 (2%)], T_8 [K_2HPO_4 (1%) + KNO_3 (1%)], T_9 [KH_2PO_4 (1%) + KNO_3 (1%], T_{10} [K_2HPO_4 (1%) + thiourea (0.5%)], T_{11} [KH_2PO_4 (1%) + thiourea (0.5%)], T_{12} [KNO_3 (1%) + thiourea (0.5%)] were applied. T_{13} was taken as control and remained untreated during the course of experiment. The foliar spray of chemicals was performed thrice during the last week of September to November at 20 days interval. Date of panicle initiation was recorded by daily field visits during flowering time. Number of male, female and total flowers per panicle was counted in selected panicles of each direction by means of visual counting. Sex ratio was calculated by dividing the number of male flowers with number of female flowers of the same panicle. Flowering intensity was calculated by dividing the number of flowering shoots with total number of shoots in all directions. Flowering advancement was calculated by comparing the date of flowering in different treatments with the date of flowering in control. The time taken to fruit set was determined by counting the number of days between anthesis to the date of fruit set. The fruit set per panicle was calculated by counting the number of fruits in each selected panicle in all the directions by working out the average of data, thus obtained (replication wise). The percentage of fruit drop was calculated on the basis of the total number of fruit dropped from initial fruit set stage to harvesting maturity. Fruit cracking was observed by tagging selected panicles in each direction of the trees. Days taken to fruit maturity were determined by counting the number of days from the day of panicle initiation (bud burst) to the fruit maturity stage. Yield per hectare was recorded by weighing the total harvested fruits in each replication of each treatment by using weighing balance. Average weight of fruits, aril and seed was measured using electronic weighing balance. Pulp recovery per cent was calculated by diving average weight of aril by average weight of fruit. The data was statistically analysed as per the method of Gomez and Gomez (1984) [10]. Data was subjected to ANOVA (Analysis of Variance) using Least Significant Difference at 5% level of significance.

Result and Discussion

Earliest panicle emergence was observed on 16th February in T_1 [ethrel @ 400 ppm] and T_2 [KNO_3 @ 1%] whereas T_8 [K_2HPO_4 @ 1% + KNO_3 @ 1%] and T_{13} [control] recorded late panicle emergence on 19th February (Table 1). Ethrel or Ethephon (ethylene releasing substances) are known for leaf expansion (Khan, 2005; Khan *et al*., 2008) [16, 17] and chlorophyll synthesis at lower concentration (Grewal *et al*., 1993) [11]. Ethylene releasing compounds have also shown significant effect on leaf photosynthetic rate (Pua and Chi, 1993) [32]. The increased photosynthesis and subsequently high carbohydrate accumulation in shoots might have resulted in early maturation of shoots for inducing early panicle. The results obtained are in close conformity with the findings of Mandal *et al.* (2014) [21]. Potassium nitrate (KNO_3) has also shown profound effect in stimulating early flowering in trees growing in tropical and subtropical regions (Adam, 1986) [1]. The duration of flowering in all the treatments varied from

17-20 days. The duration was minimum (17 days) in T_2 [KNO3 @ 1%] whereas T_{13} [control] had maximum flowering duration of 20 days. All the treatments had a significant effect on flowering advancement as compared to control (T_{13}). The maximum advancement of flowering (3 days) was recorded in T_2 [KNO_3 @ 1%] (Table 1). Similar result of flowering advancement (4-5 days) by application of KNO_3 was reported by Dalal *et al*. (2005) [4]. The maximum number of female flowers (324.63) and total flowers (836.39) per panicle were observed in T_2 [KNO_3 @ 1%] whereas it was minimum in T_{13} [control]. Kulkarni (2014) [18] reported KNO_3 application increases number of flowers by forcing and sensitizing the flower buds to respond to the floral stimulus which is present in stems. Davenport (2003) [5] observed 100% reproductive shoots and profuse flowering when KNO_3 was applied on older shoots while 2-3 months old shoots resulted in vegetative growth in response to KNO_3. Increase in percent of flowering due to KNO_3 might be due to increased concentrations of zeatin or zeatin riboside which are flower induction promoters present in it (Eric Guevara *et al*., 2012) [6]. The dose and time of application of flower inducing chemicals has a significant effect on the kind of response obtained. In the present study, significant response of increased number of flowers was observed with 1% KNO_3. The results obtained are in support with the findings of Mitra and Sanyal (2001) [26] who reported KNO_3 induced flowering in litchi cv. Bombai. Garad *et al*. (2013) [9] also found increased number of hermaphrodite flowers by application of KNO_3. Significant difference for the sex ratio was observed among all the treatments. The sex ratio (male: female) varied from 1.57 to 1.91 in different treatments. Minimum sex ratio (1.57) was observed in T_2 (KNO_3 @ 1%) whereas T_{13} (control) recorded the maximum sex ratio (1.91).

The flowering intensity was remarkably improved in all the treatments. It was maximum (70.51%) in T_9 [KH_2PO_4 @ 1% + KNO_3 @ 1%] whereas T_{13} [control] recorded minimum (61.82%) flowering intensity (Table 1). Potassium plays an important role in increasing absorption of Mg, an element that is fundamental in the floral formation and promotes the synthesis of nucleic acids (Feucht, 1982) [8]. Potassium compounds are also known to affect the nitrogen level of the plant and specific products of N metabolism and amino acids plays a direct role in the initiation and differentiation of floral buds in the shoots. Marschner (2002) [22] reported reduced flower bud formation in the shoots in case of a deficiency of P. Increased flowering intensity in the shoots by KH_2PO_4 might be due to the fraction of K in it, that stimulates photosynthesis and transports photo assimilates, which is important for the formation of flowers (Swietlik, 2003) [38] whereas nitrate form (NO_3^-) in KNO_3 increases levels of arginine, compound which can promote flowering (Niu *et al*. 2007) [28]. Similar results of increased flowering intensity by application of Potassium are reported in other fruits (Agusti, 2003). The results are in close conformity with the findings of Garad *et al*. (2013) [9] who reported increased flowering intensity by KH_2PO_4 (1%) + KNO_3 (1%). The time taken from flowering to fruit set in all the treatments varied from 16 to 20 days (Table 2). The treatment T_1 [Ethrel @ 400 ppm] took the least time (16 days) to fruit set whereas T_{13} [control] took maximum time (20 days) for fruit set (Table 2). Similar findings of reduced time period for fruit setting by ethrel were observed by Mandal *et al*. (2014) [21]. Fruit set per panicle in all the treatments were significantly higher than T_{13} [control]. The initial fruit set per panicle was maximum (59.49) in T_2 [KNO_3 @ 1%] followed by T_1 [Ethrel @ 400 ppm]. Similar results regarding increased fruit set per panicle by KNO_3 was reported by Mitra and Sanyal (2001) [26] in litchi and Yeshitela *et al*. (2004) [44] in mango. The treatment T_2 [KNO_3 @ 1%] had the least fruit drop (75.90%) as compared to other treatments. The results obtained are in support with findings of Sharma *et al*. (1990) [36] who recorded reduced fruit drop and increased fruit retention by foliar application of KNO_3 in mango cv. Langra. Days taken to maturity among all the treatments varied from 51 to 56 days. From fruit set to maturity, growth of litchi fruit occurs in three phase. During first phase, pericarp, seed coat and embryo develop. Second phase is characterized by rapid growth of embryo and beginning of aril development while in last third phase, aril development and maturation takes place (Joubert, 1986; Wang *et al*., 2017) [14, 43]. Fruits attained the maturity stage when they developed a bright red blush with flattened tubercles. The minimum days for maturity (51 days) were observed in T_1 [ethrel @ 400 ppm] and T_7 (KH_2PO_4 @ 2%) treatments whereas the T_{13} [control] took maximum days for maturity (56 days)**.** Maximum fruit yield (43.82 kg/tree) was obtained in T_2 [KNO_3 @ 1%] whereas the minimum yield (34.08 kg/tree) was recorded in T_{13} [control] (Table 2). It is well known fact that yields depends upon reserve food stored by plants as well as many other internal and external factors. Higher fruit set and reduced fruit drop in KNO_3 treated plants subsequently resulted in higher yield. The present results are in accordance with the findings of Sangwan *et al*. (2008) [34] who reported increased yield by the foliar application of KNO_3. Fruit weight is considered as most important external factor in determining fruit quality as it greatly influences consumers appeal. Foliar application of all the chemicals significantly increased the fruit weight. The maximum fruit weight (20.99 g) was observed in treatment T_1 [ethrel @ 400 ppm] whereas it was minimum (18.46 g) in T_{13} [control]. The increased fruit weight might be due to more rapid increase in the number of cell during the growth and development of the fruit. The actively proliferating parenchyma cells in the aril are initially elongated and slim, but become irregular in shape during the later phase of isodiametric growth. The involvement of ethylene in the growth of these cells seems probable, since this substance is active in the growth of other fruits. Similar results were observed by Saxena (1994) [35] and Jones *et al.* (1993) [13] who reported increased fruit weight by foliar application of ethrel. The aril weight in all the treatments was statistically found significant over control.

The maximum aril weight (17.30g) was recorded in T_1 [ethrel @ 400 ppm] while minimum aril weight (14.33 g) was observed in T_{13} [control]. Maximum pulp recovery percent (81.49%) was recorded in T_4 [KH_2PO_4 @ 1%] whereas T_{13} (control) recorded minimum (77.61%) pulp recovery (Table 2). The K fraction of the KH_2PO_4 is involved in Hill reaction (for generation of NADPH and ATP, together with ionic equilibrium, electron transport, and proton-motive force) and Calvin and Benson cycle (sugar production and transport, partitioning of photoassimilates) of the photosynthesis (Tighe-Neira *et al*., 2018) [39] whereas phosphate (PO_4) fraction bounds with the sugars to make different kinds of carbohydrates and starches, which are then ultimately transformed into organic compounds of the edible portion, thus increases the share of edible portion in the fruits (Rice, 2016) [33].

Table 1: Effect of foliar spray of Ethrel, potassic compounds and Thiourea on flowering attributes of Litchi Cv. Rose scented

Symbols	Treatments	Date of Panicle Initiation	Duration of flowering	Advancement in Flowering (Days)	Flowers/panicle (Male)	Flowers/panicle (Female)	Total flowers/ panicle	Sex Ratio (M/F)	Flowering Intensity (%)
T_1	Ethrel (400ppm)	16.02.2016	18	2	491.46	307.81	799.27	1.60	65.13
T_2	KNO_3 (1%)	16.02.2016	17	3	511.76	324.63	836.39	1.57	65.80
T_3	K_2HPO_4 (1%)	18.02.2016	19	1	414.13	248.48	662.61	1.66	66.84
T_4	KH_2PO_4 (1%)	17.02.2016	19	1	406.34	236.00	642.34	1.74	61.28
T_5	Thiourea (0.5%)	18.02.2016	20	0	396.78	220.09	616.87	1.80	66.26
T_6	K_2HPO_4 (2%)	18.02.2016	19	1	415.96	248.10	664.07	1.67	65.06
T_7	KH_2PO_4 (2%)	17.02.2016	19	1	368.39	256.16	624.56	1.64	64.21
T_8	K_2HPO_4 (1%) + KNO_3 (1%)	19.02.2016	19	1	458.19	244.98	703.18	1.87	65.13
T_9	KH_2PO_4 (1%) + KNO_3 (1%)	18.02.2016	19	1	456.29	246.47	702.76	1.85	70.51
T_{10}	K_2HPO_4 (1%) + Thiourea (0.5%)	18.02.2016	20	0	430.99	266.06	697.05	1.62	62.21
T_{11}	KH_2PO_4 (1%) + Thiourea (0.5%)	18.02.2016	18	2	393.21	241.09	634.30	1.64	66.71
T_{12}	KNO_3 (1%) + Thiourea (0.5%)	17.02.2016	18	2	462.70	275.75	738.45	1.67	69.10
T_{13}	Control	19.02.2016	20	0	390.49	203.94	594.43	1.91	61.82
	CD at 5%	-	-	-	NS	36.16	86.88	0.20	3.74
	SEm±	-	-	-	20.01	12.39	29.78	0.06	1.29

Table 2: Effect of foliar spray of Ethrel, potassic compounds and Thiourea on fruiting attributes of Litchi Cv. Rose scented

Symbols	Treatments	Time taken to fruit set (days)	Fruit set per Panicle	Fruit drop (%)	Fruit cracking (%)	Days taken to maturity	Yield (Kg/tree)	Fruit weight (g)	Aril weight (g)	Seed weight (g)	Pulp recovery (%)
T_1	Ethrel (400ppm)	16	57.08	81.58	14.6	51	41.29	20.99	17.30	2.00	80.28
T_2	KNO_3 (1%)	18	59.49	75.90	15.66	53	43.82	20.06	16.16	2.04	80.37
T_3	K_2HPO_4 (1%)	17	46.07	81.79	14.15	52	40.51	19.61	15.19	2.03	77.95
T_4	KH_2PO_4 (1%)	19	49.35	82.08	11.46	54	38.16	19.33	15.74	2.16	81.49
T_5	Thiourea (0.5%)	18	48.76	82.86	12.09	54	35.15	19.57	15.77	2.19	80.58
T_6	K_2HPO_4 (2%)	18	41.79	83.17	15.70	53	40.85	19.08	15.47	2.05	81.05
T_7	KH_2PO_4 (2%)	19	54.90	80.77	16.46	51	37.72	18.60	15.22	2.09	81.08
T_8	K_2HPO_4 (1%) + KNO_3 (1%)	19	52.36	86.48	18.82	54	41.30	20.08	15.70	2.60	78.33
T_9	KH_2PO_4 (1%) + KNO_3 (1%)	18	43.99	82.51	19.04	54	41.61	19.66	15.44	2.15	78.50
T_{10}	K_2HPO_4 (1%) + Thiourea (0.5%)	19	55.94	76.27	17.76	55	42.34	18.81	15.20	2.01	80.88
T_{11}	KH_2PO_4 (1%) + Thiourea (0.5%)	18	43.07	91.08	18.86	54	36.53	18.57	14.44	2.24	79.47
T_{12}	KNO_3 (1%) + Thiourea (0.5%)	17	45.22	77.86	15.82	53	37.56	19.41	15.11	2.30	77.88
T_{13}	Control	20	39.84	89.24	19.50	56	34.08	18.46	14.33	2.32	77.61
	CD at 5%	-	11.81	7.02	NS	-	5.71	1.36	0.84	NS	2.97
	SEm±	-	4.05	2.40	3.74	-	1.95	0.46	0.28	0.12	1.16

Note: *CD= Critical difference, SEm± = Standard error of mean

Conclusion

The present study indicated that foliar application of chemicals is highly effective for improving flowering and fruiting in case of litchi. The potassic form of chemicals mainly KNO_3 (1%) significantly improved the flowering attributes particularly early and maximum flowering, highest fruit set and subsequently higher yield whereas highest fruit and aril weight was obtained with 400ppm ethrel spray.

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