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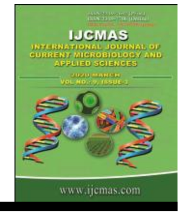

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Foliar Feeding of Brassinosteriod: A Potential Tool to Improve Growth, Yield and Fruit Quality of Strawberry (*Fragaria* × *ananassa* Duch.) under Non-Conventional Area

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A B S T R A C T

The present investigation was carried out during 2018-19 in the Department of Horticulture (Fruit and Fruit Technology), BAC, Sabour to study the Efficacy of foliar feeding of brassinosteroid at different growth stage of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn for improving growth, yield and quality attributes. The experimental finding revealed that plant height, leaf size increased significantly in the treatments where brassinosteroid was applied repeatedly at vegetative, flowering and again at fruiting stage, irrespective of their concentration; however, runner per plant was recorded maximum in control (4.67). However, maximum yield per acre area (12.93 tonnes) was recorded in 0.2 ppm brassinosteroid spray each at vegetative, flowering and fruiting stage with at par result in 0.3 ppm spray each at vegetative, flowering and fruiting stage (12.92 tonnes) and 0.1 ppm spray at all these three stages (12.44 tonnes). Fruit size (length and width) as well as sugar: acid ratio were also measured significantly higher in the treatments where brassinosteroid was applied repeatedly at vegetative, flowering and again at fruiting stage, irrespective of their concentration with maximum fruit length and width in T_9*i.e.*0.2 ppm brassinosteroid spray each at all three stages (41.73 mm and 32.60 mm, respectively) and maximum sugar :acid ratio in T_5*i.e.*in 0.1 ppm spray at all these three stages(15.21) with minimum in control (28.32 mm, 26.03 mm and 5.50, respectively). Hence, it can be concluded that the foliar feeding of brassinosteroid repeatedly at vegetative, flowering and fruiting stage is the best treatment to increase the yield potentiality of strawberry cv. Winter Dawn with improved fruit quality under subtropical condition of Bihar, India.

Introduction

Strawberry (*Fragaria* × *ananassa* Duch.), an aggregate fruit of Rosaceae family, occupies a significant place in fruit industry, since it is cultivated both in plains as well as in hills. It is an herbaceous crop with prostate growth habit, which behaves as an annual in subtropical region and perennial in temperature region and has gained the status of being one of the most important soft fruit of the world after grape. Being rich in vitamin A (60 IU/100g), vitamin C (30-120 mg/100g), fiber, iron, pectin content (0.55%) and ellagic acid, which has anti cancerous property, strawberry is mainly used as fresh fruit. Besides, antioxidants, it also contain very good amount of phenols, flavonoids, dietary glutathionine which also exhibit a high level of antioxidant capacity against free radical species. In addition, strawberry fruits are eye-catching with very good aroma and flavor.

In India, it is cultivated commercially in the Himanchal Pradesh, Uttar Pradesh, Maharashtra, West Bengal, Nilgiri hills, Delhi, Haryana, Punjab and Rajasthan. However, it can grow anywhere in Indian subcontinent under assured irrigation and transport facilities. Due to very high return per unit area and production of berries within a few months of planting, the crop has assumed economic importance throughout the world (Zargar *et al.,* 2008). This is the reason for which the area and production of the crop throughout the world has increased many folds over the past decade. In India, currently it is growing over 1000 hector area with annual production of 5000 metric tonnes (Anonymous, 2017) and its area has already been expanded from the foot hills to subtropical plains. However, the quality of the fruits under subtropical region is quite inferior as compare to temperate region. In addition, the productivity of the crop is also quite low (5 t/ha) in India as compared to other strawberry growing countries. Therefore, it is one of the major challenges for the fruit researches to improve the quality as well as the productivity of the strawberry particularly under subtropical plains.

There are several well established low cost strategies reported throughout the world to enhance the quality and productivity of different agri-horticultural crops. Among them, application of optimum dose of macro and micronutrients, use of intercrops, adaptation of HDP system, drip irrigation system, scientific training and pruning technique, use of different plant growth regulators and biofertilizers play major role to enhance the productivity of different fruit crops (Kumar *et al.,* 2019; Thakur *et al.,* 2018; Kundu *et al.,* 2013a, Kundu *et al.,* 2013b, Kundu *et al.,* 2013c). Among, all these techniques, exogenous application of various plant growth regulators has been found effective for stimulation of fruit growth and maturity. Higher yield with improved fruit quality by the use of plant growth regulators has been reported in mango (Wahdan *et al.,* 2011), citrus (Gonzales and Borroto, 1987), apple (Turk and Stopar, 2010) and other fruits. Exogenous application of PBRs has also been reported to improve the endogenous levelsof phytohormones (Al-Duljaili *et al.,* 1987), mineral nutrients (Bist, 1990) which stimulate the growth, flowering and fruiting of different fruit crops (Al-Duljaili *et al.,* 1987; Randhawa *et al.,* 1959).Therefore, to improve the productivity of quality strawberry fruits in the country, it is the urgent need to study the performance of PBRs on growth, yield and quality of strawberry.

Among different PGRs, brassinosteroid plays an important role in various aspects of plant physiological responses including cell division, cell elongation, vascular differentiation, flowering, pollen growth and photomorphogenesis (Clouse 2011). Several reports have also shown that brassinosteroids are involved in fleshy fruit development and ripening of tomato fruit (Vardhini and Rao 2002;Lisso *et al.,* 2006), grape berry (Symons *et al.,* 2006)and cucumber (Fu *et al.,* 2008).A report has also suggests that brassinosteroid play important role in fruit ripening of strawberry(Bombarely *et al.,* 2010). However, the literature on the exact response of brassinosteriod on strawberry plant to improve yield and quality is still scanty. Keeping these views in mind, the present research work was formulated to study the impact of foliar spray of brassinosteriod at different growth stage of strawberry on growth, yield and quality of the fruit.

Materials and Methods

Treatment to experimental plants

After preparation of working solution of brassinosteroid for different treatment, the solution was sprayed over the experimental strawberry plants during vegetative, flower initiation and fruiting stage with the following treatment details- T1: Water spray (Control), T2:0.1 ppm Brassinosteroid at vegetative stage. T3: 0.1 ppm Brassinosteroid at vegetative and flowering stage, T4: 0.1 ppm Brassinosteroid at vegetative and fruit setting stage, T5: 0.1 ppm Brassinosteroid at vegetative stage, flowering and fruit setting stage, T6: 0.2 ppm Brassinosteroid at vegetative stage, T7: 0.2 ppm Brassinosteroid at vegetative and flowering stage, T8: 0.2 ppm Brassinosteroid at vegetative and fruit setting stage, T9: 0.2 ppm Brassinosteroid at vegetative stage, flowering and fruit setting stage, T10: 0.3 ppm Brassinosteroid at vegetative stage, T11: 0.3 ppm Brassinosteroid at vegetative and flowering stage, T12: 0.3 ppm Brassinosteroid at vegetative and fruit setting stage and T13: 0.3 ppm Brassinosteroid at vegetative stage, flowering and fruit setting stage

Observation taken

Growth: Plant height, leaf length, leaf breadth was measured by using measuring scale while total number of runner produced on each plant during its entire growing period was counted manually.

Yield: On the other hand, all the fruits from an individual plant were picked manually in each harvesting and weighted them on digital weighing balance. At the end of last harvesting, yield/plant was calculated by adding the value of fruit weight in each harvesting. Thereafter, yield per acre area was calculated by using following formula and expressed in tonnes/ha.

$$\text{Yield/acre} = \text{Yield/plant} \times \text{No. of plants accomodated in one acre (22500)}$$

Fruit quality: Fruit length was measured with the help of digital vernier caliper. It was measured from the base of the fruit stalk to the calyx end and expressed in millimeter (mm). Similarly, fruit breadth was also measured with the help of digital vernier caliper at the point where it was observed maximum and expressed in millimeter (mm). However, total number of achiens/cm^{2}of fruit surface was calculated during the ripening of the fruit in each treatment by using graph paper. While, sugar:acid ratio was determined by dividing the total sugar content with titratable acidity for ten individual fruits under each replication and average value was calculated thereafter. Sugar content in the ripe fruit was estimated by Lane and Eynone (1923) method.

Statistical analysis

The experiment was laid out in randomized block design with three replications. The observations were analysed by using OPSTAT software (OPSTAT, CSS HAU, Hisar India).

Results and Discussion

Vegetative growth

The results on the response of brassinosteroid on plant height of strawberry cv. Winter Dawn indicate a significant variation among the treatment (Table 1). Among different treatment maximum plant height (16.66 cm) was observed in the treatment consist of foliar feeding of brassinosteroid @ 0.3 ppm each at vegetative, flowering and fruiting stage. However, the control plant had least plant height (13.22 cm) which was statistically at par with the treatment of 0.1 ppm brassinosteroid spray at vegetative stage only (14.19 cm).

A perusal of data pertaining to leaf size indicated that the leaf length and breadth differed significantly due to the effect of various treatments of brassinosteroid (Table 1). As compared to control, leaf length has increased in each and every treatment and it was observed maximum in foliar feeding of brassinosteroid @ 0.2 ppm each at vegetative, flowering and fruiting stage (9.31 cm) with at par result in foliar feeding of brassinosteroid @ 0.3 ppm each at vegetative, flowering and fruiting stage (9.25 cm). However, it was recorded minimum in brassinosteroid application @ 0.3 ppm each at vegetative and fruiting stage (8.25 cm). Similar pattern was also observed for leaf breadth with maximum in 0.3 ppm brassinosteroid spray each at vegetative, flowering and fruiting stage (7.91 cm) and minimum in control (6.16 cm).

The influence of brassinosteroid on runner production per plants was observed statistically significant among all the treatment (Table 1). Number of runner per plant was recorded maximum in control (4.67) with par result in brassinosteroid spray @ 0.1 ppm at vegetative stage only (4.33) and 0.2 ppm brassinosteriod spray at vegetative stage (4.00); however, it was recorded minimum in 0.3 ppm brassinosteriod spray each at vegetative, flowering and fruiting stage with similar number in brassinosteroid spray @ 0.3 ppm at vegetative and fruiting stage only (1.67). In all other treatments, number of runner production per plant was also reduced as compared to control.

Yield and fruit quality attributes

A perusal of data on total fruit yield per plant of strawberry cv. Winter Dawn showed significant variations among different treatments (Table 2). Fruit yield was recorded maximum in 0.2ppm each at vegetative, flowering and fruiting stage (12.93 t acre^{-1}) with at par result in 0.3 ppm brassinosteriod spray each at vegetative, flowering and fruiting stage (12.92 t acre-^{1}) and brassinosteroid spray @ 0.1 ppm each at vegetative, flowering and fruiting stage (12.44 t acre^{-1}) which were 1.46, 1.46 and 1.41 times to control (8.85 t acre^{-1}).In addition, fruit yield per plant was also increased significantly in T_8 (brassinosteroid spray @ 0.2 ppm each at vegetative and fruiting stage only), T_{11} (brassinosteroid spray @ 0.3 ppm each at vegetative and flowering stage only),T_7 (brassinosteroid spray @ 0.2 ppm each at vegetative and flowering stage only),T_4 (brassinosteroid spray @ 0.1 ppm each at vegetative and fruiting stage only), T_{12} (brassinosteroid spray @ 0.3 ppm at vegetative and fruiting stage only) and in T_3 (brassinosteroid spray @ 0.1 ppm each at vegetative and flowering stage only) (1.33, 1.31, 1.31, 1.31, 1.31 and 1.27 times to control). However, yield was recorded minimum in control with at par result inT_2 (brassinosteroid spray @ 0.1 ppm at vegetative stage only), T_6 (0.2 ppm brassinosteriod spray at vegetative stage) and T_{10} (brassinosteroid spray @ 0.3 ppm at vegetative stage only).

A significant variation in fruit size with respect to fruit lengthand width was observed as a result of different concentration of brassinosteroid application at different growth stage of strawberry cv. Winter Dawn. Data presented in Table 2 clearly indicates that the maximum fruit length was obtained in T_5 (brassinosteroid spray @ 0.1 ppm each at vegetative, flowering and fruiting stage) (1.51 times to control) with at par length in T_9

(0.2ppm brassinosteriod spray each at vegetative, flowering and fruiting stage) and T_{13} (0.3 ppm brassinosteriod spray each at vegetative, flowering and fruiting stage) (41.73 mm and 41.60 mm, respectively). Apart from this, fruit length was also increased significantly as compared to control in T_8 (brassinosteroid spray @ 0.2 ppm each at vegetative and fruiting stage only), T_4 (brassinosteroid spray @ 0.1 ppm each at vegetative and fruiting stage only) and T_{12} (brassinosteroid spray @ 0.3 ppm at vegetative and fruiting stage only) (1.23,1.21 and 1.20 times to control, respectively). However, it was measured minimum in control (28.32 mm) with par result in T_2, T_6, T_{10}, T_7, T_{11}, T_3 (30.23 mm, 30.53mm, 30.87 mm, 31.70 mm, 31.93 mm and 32.08 mm, respectively). Similar trend was also observed for fruit width in strawberry cv. Winter Dawn as influenced by different concentration of brassinosteroid application at different growth stage of the plant with maximum value in T_9(0.2ppm each at vegetative, flowering and fruiting stage) (32.60 mm)and minimum in control (26.03 mm).

Table.1 Effect of brassinosteroid on vegetative growth of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn

Treatment	Plant height (cm)	Leaf length (cm)	Leaf breadth (cm)	Runner number plant^{-1}
T_1- Control	13.22	8.33	6.16	4.67
T_2- 0.1 ppm BRs at vegetative stage	14.19	8.26	7.01	4.33
T_3- 0.1 ppm BRs at vegetative and flowering stage	14.93	8.29	7.56	3.33
T_4- 0.1 ppm BRs at vegetative and fruit setting stage	14.47	9.03	7.26	2.00
T_5- 0.1 ppm BRs at vegetative, flowering and fruit setting stage	15.70	8.56	7.68	2.00
T_6- 0.2 ppm BRs at Vegetative stage	14.30	8.75	7.15	4.00
T_7- 0.2 ppm BRs at vegetative and flowering stage	15.07	8.22	7.45	3.00
T_8- 0.2 ppm BRs at vegetative and fruit setting stage	14.70	8.75	7.88	2.00
T_9- 0.2 ppm BRs at vegetative, flowering, and fruit setting stage	15.57	9.31	7.11	2.00
T_{10}- 0.3 ppm BRs at vegetative stage	14.37	8.82	7.25	3.67
T_{11}- 0.3 ppm BRs at vegetative and flowering stage	15.18	8.35	7.44	3.00
T_{12}- 0.3 ppm BRs at vegetative and fruit setting stage	14.93	8.25	7.25	1.67
T_{13}- 0.3 ppm BRs at vegetative flowering and fruit setting stage	16.66	9.25	7.91	1.67
CD (≤0.05)	1.75	0.56	1.25	2.5
CV (%)	5.98	4.85	6.45	6.89

Table.2 Effect of brassinosteroids on yield and fruit of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn

Treatment	Fruit yield (t acre^{-1})	Fruit length (mm)	Fruit width (mm)	No. of achiens cm^{-2} of fruit	Sugar: acid ratio
T_1- Control	8.85	28.32	26.03	16.35	5.50
T_2- 0.1 ppm BRs at vegetative stage	9.68	30.23	27.90	15.00	6.08
T_3- 0.1 ppm BRs at vegetative and flowering stage	11.25	32.08	29.83	14.56	7.86
T_4- 0.1 ppm BRs at vegetative and fruit setting stage	11.56	34.37	31.73	14.05	12.24
T_5- 0.1 ppm BRs at vegetative, flowering and fruit setting stage	12.44	42.78	32.23	13.85	15.21
T_6- 0.2 ppm BRs at Vegetative stage	9.95	30.53	27.87	13.05	5.88
T_7- 0.2 ppm BRs at vegetative and flowering stage	11.58	31.70	29.43	10.14	8.89
T_8- 0.2 ppm BRs at vegetative and fruit setting stage	11.77	34.90	31.63	11.24	11.28
T_9- 0.2 ppm BRs at vegetative, flowering, and fruit setting stage	12.93	41.73	32.60	9.08	14.57
T_{10}- 0.3 ppm BRs at vegetative stage	10.06	30.87	27.63	12.66	6.04
T_{11}- 0.3 ppm BRs at vegetative and flowering stage	11.58	31.93	30.10	11.57	8.46
T_{12}- 0.3 ppm BRs at vegetative and fruit setting stage	11.54	33.93	31.83	9.58	10.97
T_{13}- 0.3 ppm BRs at vegetative flowering and fruit setting stage	12.92	41.60	32.33	9.12c	13.38
CD (≤0.05)	1.63	6.21	4.85	3.56	2.56
CV (%)	5.24	8.91	7.56	7.89	5.68

The number of achiens/cm^2 fruit surface of strawberry cv. Winter Dawn was varied significantly in different concentration of brassinosteroid treatment (Table 2). It was estimated maximum in control (16.35) with at par number and the number has reduced significantly in different brassinosteriod treatment with minimum in 0.2 ppm brassinosteriod spray each at vegetative, flowering and fruiting stage (9.08).

It is envisaged from the data presented in table 2 that the ratio of total sugar: acid increased significantly in all the brassinosteriod treated plants as compared to control. In control the ratio was only 5.50

which was minimum among all the treatment; however, it was recorded maximum in the treatment consist of brassinosteriod application in all the three different growth stages irrespective of concentration (T_5, $T_9$and T_{13} @ 15.21, 14.57 and 13.38 respectively).

Vegetative growth of the plants

In the present study, the growth attributes *viz*. tree height, leaf size (length and breadth) has increased significantly over control in all the brassinosteroid treatment. This increment of vegetative growth by brassinosteroid application is mainly due to the active participation of brassinosteroid to cell elongation and cell multiplication (Mussig 2005 and Montoya *et al.,* 2005) particularly in the new vegetative shoots.

However, both plant height and leaf size was recorded maximum in the treatment where brassinosteroids were applied during three different growth phases (T_5, T_9 and T_{13}) followed by two growth phases (T_3, T_7, T_{11} and T_4, T_8, T_{12}) and only at vegetative stage (T_2, T_6 and T_{10}).

Generally the action of brassinosteroid is very quick and it also degrades very quickly (Janeczko *et al.,* 2010). Hence, repeated application of brassinosteriodensures long lasting action which was reflected in this experiment.

In the present study, no clear trend was observed in respect of runner production. However, it was recorded maximum in control (4.67 plant^{-1}) treatment and in brassinosteroid application @ 0.1 ppm only at vegetative stage (4.33 plant^{-1}). The production of higher number of runner per plant in these two treatment might be associated with the lower reproductive growth resulting accumulation of more energy followed by production of more number of runner.

Yield and fruit quality attributes

In the current investigation yield acre^{-1}, berry size and other fruit quality attributes has increased significantly in all the brassinosteroid sprayed plots as compared to control. However, yield was recorded maximum in the plots treated with brassinosteroid either during all the three developmental phase of the plant (T_5, T_9 and T_{13}) or during vegetative as well as fruiting stage (T_4, T_8 and T_{12}) irrespective of their concentration. This drastic increase in fruit yield by the brassinosteroid spray during reproductive growth phase was also reported by Gomes *et al.,* (2006) in yellow passion fruit which might be due to better accumulation of photosynthates in treated plants, stimulated by brassinosteroid application. In addition, extensive studies have indicated that cell division and cell elongation are significantly influenced by brassinosteroid spray alone, or in combination with other phytohormones (Jager *et al.,* 2005; Matusmoto *et al.,* 2016). This significant increase in the growth and promotion of cell elongation could be associated with brassinosteroid- induced elevation of carbohydrate supply by means of the up-regulation in the activity of an extra cellular invertase enzyme (Nakajima and Toyama 1999; Goetz *et al.,* 2000). Further, Vardhini and Rao (1998) and Hayat *et al.,* (2000) explanation that yield increase in fruit trees by brassinosteroid treatment may be related to improvement in the assimilation efficiency of photosynthetic carbon and protein biosynthesis. Moreover, from the available literature, it is clear that brassinosteroid is likely to be involved in cell division, cell expansion, reproductive development, pollen tube formation and differentiation of plant tissues rapidly (Clouse 2002; Sasse 2003) resulting increased berry yield with bigger fruit size and high sugar acid ratio.

In conclusion, the present investigation confirms that the action of brassinosteroid is very quick and it also degrades very quickly. Therefore, repeated application of brassinosteroid reflected its long lasting action for improving vegetative growth of strawberry cv. Winter Dawn with increased yield of better quality fruit.

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