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Impact of foliar application of plant growth regulators on seed filling and seed multiplication rate in groundnut (*Arachis hypogaea* L.)

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Abstract
The investigation was directed to assess the impact of foliar spray with plant growth regulators on flowering characteristics of groundnut (*Arachis hypogaea* L.) var. TMV 7 and their corresponding influence on pod and seed attributes. The plants were sprayed with plant growth regulators such as Ethrel, Chlorocholine chloride (CCC), Maleic Hydrazide (MH), Naphthalic Acetic Acid (NAA) and Mepiquat chloride (PIX) in different concentrations at 60 days after sowing (DAS). The weight of pod and seed yield plant^{-1} obtained in the plants sprayed with plant growth regulators recorded statistically significant variation. In all the treatments, the number of flowers in the later stages were reduced which reduced the number of immature pods and increased the number of double seeded pods, eventually contributing to higher seed yield than the untreated (control) plants. Among the treatments, the highest pod yield per plant was recorded in NAA 200 ppm (29.33 g) followed by Ethrel 400 ppm (24.88 g) when compared with the control (15.79 g) in which the lowest yield was obtained. These treatments can be utilised for increasing the efficiency of pod filling thereby increasing the seed yield in groundnut.

Keywords: Groundnut, growth regulators, indeterminate flowering, pod filling, seed yield

1. Introduction

Groundnut (*Arachis hypogaea* L.) is an important leguminous oilseed crop which is commonly known as poor man's nut as it is a cheaper source of protein when comparable to other nuts like cashew nut. It is also called as peanut, monkey nut and goober nut. Groundnut seed contains 44 to 56% oil and 22 to 30% protein on dry seed basis and is a rich wellspring of minerals (Phosphorus, Calcium, Magnesium and Potassium) and vitamins (Kaba *et al.*, 2014) [5].

As a seed crop, the flowering plays a crucial role in deciding the yield of groundnut. Usually, the flowering commences within 3 weeks after sowing and daily flower production is varied with alternations (Craufurd *et al*., 2000; Vinothini *et al*., 2018) [4, 14]. Indeterminate development in groundnut results in overlapping of growth and development periods of the vegetative and reproductive organs prompting low fruiting effectiveness. This is due to inter organ competition for assimilates and different metabolites in the later stages which leads to the inappropriate partitioning of assimilate to the developing pods and seed (Kaba *et al*., 2014) [5]. All the flowers produced are not converted to mature pods and the proportion of this conversion is the most important factors contributing to high pod yield (Songsri *et al*., 2009) [12]. Even though there is indeterminate nature of flowering, only those flowers that appear up to 70 days after sowing will form mature, filled pods during harvest (Vinothini *et al*., 2018) [14]. The flowers at the later stages will lead to immature pods thereby decrease the efficiency of seed filling and eventually reduces the seed yield (Knauft and Gorbet, 1989; Putnam *et al*., 1991; Spoljar, 1990; Vinothini *et al*., 2018) [6, 10, 13, 14].

Flower generation in plants is known to be exceptionally affected by the plant growth regulators (PGR). The higher concentration of PGRs restrains induction of flowering only when they are applied before translocation of flowering hormone is completed. In the 1930s, Mikhail Chailakhyan, working in Russia, hypothesized the presence of an all-inclusive flowering hormone, which he named florigen which stimulated the flower induction. However, high concentrations of PGR application are also an effective inhibitor of floral development and can be called as antiflorigen, even though the antiflorigens include a vast variety of compounds. PGRs restrained flowering at higher concentrations which caused no visible impacts on the plant (Salisbury, 1957) [11].

In this study, it was hypothesized that by arresting the late formed flowers, peg to pod ratio can be increased and by avoiding the immature pods, wastage of resources can be decreased eventually leading to complete development of seeds, enhanced seed weight and seed yield. With this background the current research work was initiated with the objective to standardize the foliar spray to prevent flowering in later growth stages of groundnut so as to avoid wastage of resources by way of immature pods

2. Materials and Methods

Freshly harvested pods of groundnut variety TMV 7 collected from Oilseeds Research Station, Tindivanam, Tamil Nadu Agricultural University, served as source material for the study. A field experiment was conducted at Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore during Kharif (2015) following the recommended package of practices in randomized block design (RBD). The flower initiation and the daily flower production were recorded. The plants were sprayed with plant growth regulators in different concentrations 60 days after sowing. The details of the treatments are as follows, T_1 - Ethrel 200 ppm, T_2 - Ethrel 400 ppm, T_3 - CCC 500 ppm, T_4 - CCC 1000 ppm, T_5 - MH 100 ppm, T_6 - MH 200 ppm, T_7 - NAA 100 ppm, T_8 - NAA 200 ppm, T_9 - Pix 500 ppm, T_{10} - Pix 1000 ppm and T_{11} – Control.

The observations like the number of flowers plant^{-1} (before and after spraying), total number of pods plant^{-1}, number of double seeded pods plant^{-1} (mature and immature), number of single seeded pods plant^{-1} (mature and immature), number of ill filled pods plant^{-1}, total weight of pods (g) plant^{-1}, weight of double seeded pods (g) plant^{-1} (mature and immature), weight of single seeded pods (g) plant^{-1} (mature and immature), weight of ill filled pods (g) plant^{-1}, number of seeds plant^{-1} (mature and immature) and weight of seeds (g) plant^{-1} (mature and immature) were observed for each treatments. The analysis of variance for the observations was carried out as per the standard procedures (Panse and Sukhatme, 1985).

3. Results

The experiment was conducted to evaluate the effect of foliar spraying with plant growth regulators on flowering characteristics of groundnut. Therefore, to avoid the wastage of resources to late formed flowers, and to retain flowers which could benefit from availability of sufficient days for completing the seed filling, it was essential to arrest production of new flowers after 60 DAS. Thus in the experiment, the foliar spray was taken up 60 DAS to prevent the later formed flowers which will not have the sufficient period to complete seed filling in the crop which has a duration of 110 days. Among the foliar spray treatments, NAA 200 ppm and Ethrel 400 ppm recorded the lowest number of flowers plant^{-1}, (45.68 and 112.65, respectively) after spraying, while control recorded the higher number of flowers (249.36). However, all other plant growth regulators irrespective of the concentration were effective in reducing the number of flowers produced plant^{-1}, compared to control (Table 1).

Table 1: Effect of foliar spray with plant growth regulators on flowering characteristics of groundnut var. TMV 7

Treatments (T)	No. of flowers plant^{-1}	
	Before spraying	**After spraying**
T_1 - Ethrel 200 ppm	83.13	172.34
T_2 - Ethrel 400 ppm	86.52	112.65
T_3 - CCC 500 ppm	92.36	195.32
T_4 - CCC 1000 ppm	74.68	199.68
T_5 - MH 100 ppm	95.43	207.33
T_6 - MH 200 ppm	103.02	215.66
T_7 - NAA 100 ppm	78.71	142.00
T_8 - NAA 200 ppm	84.66	45.68
T_9 - Pix 500 ppm	89.67	216.34
T_{10} - Pix 1000 ppm	81.34	222.02
T_{11} - Control	90.68	249.36
Mean	**87.29**	**179.85**
SEd	6.3262	10.7306
CD (P=0.05)	13.1963**	22.3838**

Among the treatments maximum number of double seeded mature pods plant^{-1} (28.31) was recorded in plants applied with 200 ppm NAA which were maintained with 130.34 flowers. This treatment also produced the lowest number of single seeded immature pods plant^{-1} (1.82) and number of ill filled pods plant^{-1} (0.60). As the number of flowers production plant^{-1} increased further, there were reduction in number of double seeded mature pods plant^{-1}, to a level of 49.56 percent in control (340.04 flowers). The negative pod characteristics such as number of double seeded immature pods plant^{-1}, number of single seeded mature pods plant^{-1}, number of single seeded immature pods plant^{-1} and number of ill filled pods plant^{-1} were recorded 14.69, 4.99, 4.47 and 11.73 in control, when compared to NAA 200 ppm (Table 2).

Table 2: Effect of foliar spray with plant growth regulators on number of pods plant^{-1} in groundnut var. TMV 7

Treatments (T)	Total no. of pods plant^{-1}	No. of double seeded pods plant^{-1}		No. of single seeded pods plant^{-1}		No. of ill filled pods plant^{-1}
		Mature	**Immature**	**Mature**	**Immature**	
T_1 - Ethrel 200 ppm	42.05	22.65	7.98	3.33	1.89	6.21
T_2 - Ethrel 400 ppm	38.85	25.63	6.21	2.40	1.40	3.20
T_3 - CCC 500 ppm	42.87	20.06	9.14	3.47	2.53	7.67
T_4 - CCC 1000 ppm	43.87	19.89	9.89	3.58	2.65	7.86
T_5 - MH 100 ppm	43.25	18.13	10.11	3.73	3.13	8.12
T_6 - MH 200 ppm	44.11	17.46	11.15	3.87	3.36	8.27
T_7 - NAA 100 ppm	40.88	24.02	6.39	3.01	1.73	5.73
T_8 - NAA 200 ppm	35.98	28.31	3.65	1.82	0.60	1.60
T_9 - Pix 500 ppm	44.58	16.71	11.45	4.16	3.62	8.64
T_{10} - Pix 1000 ppm	45.14	16.12	11.87	4.35	3.84	8.96
T_{11} - Control	50.16	14.28	14.69	4.99	4.47	11.73
Mean	42.89	20.30	9.32	3.52	2.66	7.09
SEd	2.4719	1.7823	1.4245	0.4619	0.1577	0.5914
CD (P=0.05)	5.1563**	3.7178**	2.9715**	0.9635**	0.3290**	1.2337**

The maximum weight of double seeded mature pods plant^{-1} (33.52 g) were recorded in plants sprayed with NAA 200 ppm, this treatment also produced the lowest weight of ill filled pods plant^{-1} (0.15 g). As the number of flowers production plant^{-1} increased further, there was reduction in weight of double seeded mature pods plant^{-1}, to a level of 56.15 percent in control (340.04 flowers). The negative pod characteristics such as weight of double seeded immature pods plant^{-1}, weight of single seeded immature pods plant^{-1} and weight of ill filled pods plant^{-1} were recorded 3.91, 2.23, and 1.98 g, respectively in Control, when compared to NAA 200 ppm (Table 3).

Table 3: Effect of foliar spray with plant growth regulators on weight of pods (g) plant^{-1} in groundnut var. TMV 7

Treatments (T)	Total wt. of pods (g) plant^{-1}	Wt. of double seeded pods (g) plant^{-1}		Wt. of single seeded pods (g) plant^{-1}		Wt. of ill filled pods (g) plant^{-1}
		Mature	Immature	Mature	Immature	
T_1 - Ethrel 200 ppm	31.83	26.72	2.39	1.51	0.63	0.58
T_2 - Ethrel 400 ppm	35.18	30.24	1.98	2.18	0.34	0.28
T_3 - CCC 500 ppm	28.12	20.66	3.45	2.54	0.78	0.69
T_4 - CCC 1000 ppm	28.60	20.48	3.82	2.65	0.91	0.74
T_5 - MH 100 ppm	27.70	18.67	4.12	2.71	1.24	0.96
T_6 - MH 200 ppm	28.07	17.98	4.90	2.81	1.32	1.06
T_7 - NAA 100 ppm	32.58	28.31	2.01	1.26	0.53	0.45
T_8 - NAA 200 ppm	36.45	33.52	1.03	1.55	0.20	0.15
T_9 - Pix 500 ppm	27.54	17.21	5.32	2.10	1.62	1.29
T_{10} - Pix 1000 ppm	28.17	16.60	5.98	2.35	1.87	1.37
T_{11} - Control	29.81	14.70	8.03	2.89	2.23	1.98
Mean	30.37	22.28	3.91	2.23	1.06	0.87
SEd	1.6469	1.4022	0.8168	0.3141	0.0976	0.0878
CD (P=0.05)	3.4354**	2.9249**	1.7039**	0.6551**	0.2036**	0.1832**

Among the treatments, NAA 200 ppm recorded the maximum number of mature seeds plant^{-1} (55.40) and weight of mature seeds plant^{-1} (29.33 g), this treatment also produced the lowest number immature seeds plant^{-1} (1.22) and weight of immature seeds plant^{-1} (0.30 g). As the number of flowers production plant^{-1} increased further, these were reduction in number of mature seeds plant^{-1}and weight of mature seeds plant^{-1}, to a level of 60.05 and 46.16 percent in control (340.04 flowers). The negative seed characteristics such as number of immature seeds plant^{-1} and weight of immature seeds plant^{-1} were recorded 1.22 and 0.30 g in Control, when compared to NAA 200 ppm (Table4).

Table 4: Effect of foliar spray with plant growth regulators on seed characteristics in groundnut var. TMV 7

Treatments (T)	No. of seeds plant^{-1}		Wt. of seeds (g) plant^{-1}	
	Mature	Immature	Mature	Immature
T_1 - Ethrel 200 ppm	41.85	3.44	23.56	0.88
T_2 - Ethrel 400 ppm	49.93	2.00	24.88	0.51
T_3 - CCC 500 ppm	36.31	3.82	20.65	0.98
T_4 - CCC 1000 ppm	39.79	3.83	19.13	1.01
T_5 - MH 100 ppm	35.11	4.00	18.92	1.23
T_6 - MH 200 ppm	30.48	4.44	17.87	1.56
T_7 - NAA 100 ppm	44.71	3.33	23.97	0.66
T_8 - NAA 200 ppm	55.40	1.22	29.33	0.30
T_9 - Pix 500 ppm	28.25	5.17	17.21	1.93
T_{10} - Pix 1000 ppm	27.24	5.33	16.57	1.98
T_{11} - Control	22.13	6.44	15.79	2.21
Mean	37.38	3.91	20.72	1.20
SEd	3.3937	0.4844	2.0029	0.0356
CD (P=0.05)	7.0792**	1.0104**	4.1780**	0.0743**

4. Discussion

Several studies have been undergone to study the effect of plant growth regulators on the developmental stages of groundnut. The present investigation in groundnut plant sprayed with NAA 200 ppm during 60 DAS after peak flowering stage hinders the flowering in later stages which helps the early formed flowers to use the source in the effectively. The results confirmed the findings of Salisbury (1957) [11] in which high concentration of NAA acted as an effective inhibitor of floral development. Further Zeeuw (1956) [15] detailed that NAA, even when applied at a moderately high concentration causes restraining flower bud development.

Assimilate availability and allocation to reproductive structures is an essential factor which decides yield of any crop (Abdi *et al*., 2007; Mondal, 2007; Barimavandi *et al*., 2010) [1, 7, 3]. Likewise, an increased pods and seed yield was recorded in plants applied with 200 ppm NAA followed by ethrel 400 ppm which enhanced the source sink relationship thereby increased mature pods. NAA is a high-productivity auxin-like plant growth regulator. So when applied in low concentrations as foliar spray on plants, it is transported basipetaly descending gradually to initiate adventitious roots and better root activities. Salisury (1957) [11] indicated that the higher concentration of auxins (NAA) restrains induction of flowering only when they are applied before translocation of flowering hormone is complete. This was the basic study for deciding the time of application of the foliar spray. Further Mukhtar *et al*. (2014) [8] demonstrate that a threshold level of assimilate (sources) supply is required for seed set (sink), and expanding the aggregate assimilate supply will enable a more prominent number of seeds to set and continue to develop (Mukhtar *et al*., 2014) [8].

Arresting of late formed flowers by spraying ethrel 400 ppm, was found to record significantly highest increase in mature pod and seed yield per plant and this confirmed the findings of Abeles (1973) [2] exogenous uses of ethylene either as a gas or with ethylene discharging compounds such as ethrel inhibit or delay the promotion of flowering. In conclusion, foliar spray of growth regulators conducted to confirm the effect on the arresting of flowers, pod as well as seed developed has put forth that, spraying of NAA 200 ppm at 60 DAS, has the potential to improve the matured, filled seed yield in groundnut.

Conclusion

In conclusion, foliar spray of growth regulators conducted to confirm the effect on the arresting of later formed flowers. As the number of flowers retained decreased, there was an increase in the number of mature pods and its weight, number of mature seed and its weight. From the results it could be concluded that of flowers that were produced from 25 to 60 days were optimum for realizing enhanced source – sink relationship in groundnut. Spraying of NAA 200 ppm at 60 DAS, has the potential to improve the matured, filled seed yield in groundnut.

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