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Article:

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Research Article

Effects of Foliar Application of Gibberellic -Acid$_3$ on the Growth and Yield of Canola (*Brassica napus* L.) Genotypes

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Abstract

Plant growth regulators play a central part in plant life. Plant hormones help to manage the equilibrium of phytohormones. Gibberellic acid, which is well known as a plant growth promoting hormone, is involved in a variety of activities related to plant growth and development. An experiment was performed at the Nuclear Institute of Agriculture, Tandojam with four promising canola genotypes in order to determine the impact of GA$_3$ foliar application on canola growth and output during the *rabi* season in 2017-2018. The results showed that growth regulators levels significantly influenced the growth and yield of canola crops. It was observed that earlier days to maturity (108.39) was recorded in genotype R00-100/6, while maximum plant height (162.75), branches per plant (10.33), siliquae per plant (362.24), siliqua length (7.39 cm), seeds per siliqua (21.49), seed index (4.50 g) and seed yield (1443.08 kg ha^{-1}) were observed with the application of GA$_3$ 5g ha^{-1} in SURHRAN-2012, followed by the application of GA$_3$ 6 g ha^{-1} genotype R00-125/12 and Rainbow (P). The results suggested that the variety SURHRAN-2012 x GA$_3$5 g ha^{-1} (foliar application) is comprised a suitable combination for obtaining maximum yield. Such application of GA$_3$ is very advantageous in the field of plant development.

Introduction

There are many oilseed crops cultivated in Pakistan and canola is one of them. Its cultivation is significant due to the importance of its oil production. The shortage of edible oil has featured regularly in the commodity market of the country. It has been estimated that only 23% of edible oil is extracted from domestic crops and the rest (77%) is imported from other countries for fulfilling the dietary needs of the public [1]. Canola (*Brassica napus* L.) is a significant oilseed crop worldwide, including Pakistan. However, due to inadequate nutrient control, canola yields are low in Pakistan [2]. Low edible oil production in the country is also due to a lack of better-adapted genotypes and a reduction of the region under oilseed crops. Since the country's population is growing and oil demand is projected to rise by 3-4 percent per year, the country needs to raise seed yield [3].

Plants are increasingly exposed to a variety of challenges that have a negative impact on their growth and productivity. [4]. In a FAO report, highlighted the requirement of devising strategies in order to compete with the worldwide impact of climate change on agriculture and food safety [5]. The genus *Brassica* L. holds the most economically valuable position in Brassica, which is a part of family Brassicaceae [6]. The deficiency of edible oil in the country may diminish if we accelerate the yield of *Brassica*.

It is very important to understand the phenomenon and working of plant hormones [7]. They are produced in one cell and travel to another cell to make changes within that cell [8, 9]. There are different sorts of hormones in plant body including Gibberellins (GAs). They are involved in many chemicals, physiological, growth related, and developmental processes, such as seed germination, plant growth, flowering development, and fruit development [10]. GAs are not only manufactured in plant cells but also in fungal and bacterial cells. They perform the functions of cell expansion and reproduction, resulting in an overall control of the organism [11]. They play a vital role in balancing the growth of internodes and in the growth and development of leaves. Moreover, they are also used to obtain rapid vegetative growth in leafy vegetable crops and grain feed [12].

Extensive studies have been conducted on GAs. A study [13] reported that they are extremely significant phytohormones involved in multiple processes, of which stem elongation, leaf extension, pollen maturation, and flowering induction are well known instances. A very small number of studies have been conducted on the foliar application of GAs to understand how these hormones react to such kind of application. Although, it is clear that diluted GAs are useful in very small amounts in foliar application since they speed up favourable conditions for the growth and development of plants at a proper time in canola [14, 15]. If plants receive the right signals from their environment at the precise time, they can show their activities very well and adapt themselves to very good morphological modulations.

Keeping in view all the above mentioned facts and in order to understand the function of GAs in foliar application in canola, a scientific investigation was put into practice to find out their effects on the growth, yield and other yield traits.

2. Methodology

2.1. Experimental Site and Crop Husbandry

An experiment was conducted at the Nuclear Institute of Agriculture, Tandojam for evaluating the effect of the foliar application of GA_3 on the growth and yield of canola (*Brassica napus* L.) genotypes. The experiment was laid out during the *rabi* season of 2017-2018 in randomized complete block design (RCBD). The treatment comprised four varieties and three concentrations of gibberellic acid with three replications, having net plot size of 5 m x 5 m. The row to row distance of 30 cm and plant to plant distance of 10 cm were maintained in all treatments. Then, the recommended doses of nitrogen, phosphorus and potassium (N : P : K = 90 : 60 : 50) kg/ha were added. A and B factors were utilized as treatments. Factor A comprised growth regulators levels =3, GA_3 4 g ha^{-1}, GA_3 5 g ha^{-1}, GA_3 6 g $ha^{-1}$and Factor B comprised four genotypes including V_1 = R00-100/6, V_2 = R00-125/12, V_3 = SURHRAN-2012, V_4 = Rainbow (P). The observations were recorded as days to maturity (days), plant height (cm), number of branches $plant^{-1}$, number of pods $plant^{-1}$, number of seeds $plant^{-1}$, seed index (g) and seed yield (kg ha^{-1}). The seed was sown with a single row hand drill. At the time of harvesting, 10 random plants were selected. Average weight of three samples was recorded for seed index and seed yield (kg ha^{-1}) was noted down on plot basis.

2.2. Statistical Analysis

Factorial analysis of variance was carried out to record the data. The differences among traits were observed according to the method of Gomez and Gomez [16], using the computer software Statistix version 8.1. Moreover, LSD was used as suggested by Steel and Torrie [17] to check the significant differences in the mean performances of characters.

3. Results

3.1 Days to Maturity

The statistical analysis of variance for this character indicated significant differences among canola genotypes along with treatments. The results revealed that maximum days to maturity (108.39) was detected in genotype R00-100/6, followed by (106.99) in Rainbow (P) and R00-125/12 (106.25), while the minimum days to maturity (104.75) was observed in SURHAN-2012. In case of growth regulators levels, maximum days to maturity (110.83) was recorded in control, followed by (107.74) and (104,41) with the application of GA_3 4 g ha^{-1} and GA_3 6 g ha^{-1}, respectively. The minimum days to maturity (103.40) was recorded in GA_3 5 g ha^{-1} (Table 1). The interaction between different varieties and growth regulators levels showed maximum days to maturity (108.39) genotype R00-100/6 x in control and the minimum days to maturity (101.33) in SURHAN-2012 with the application of GA_3 5 g ha^{-1}.

3.2 Plant Height (cm)

The statistical analysis of variance for this character indicated significant differences among canola genotypes along with treatments. The results revealed that maximum plant height (cm) (162.75) was observed in SURHAN-2012, followed by (124.83) and (120.41) in Rainbow (P) and genotype R00-125/12, respectively. The minimum plant height (83.68) was observed in genotype R00-100/6. In case of growth regulators levels, the maximum plant height (134.25) was recorded with the application of GA_3 5 g ha^{-1}, followed by (129.00) and (125.08) with the application of GA$_3$ 6 g ha^{-1} and GA$_3$ 4 g ha^{-1}, respectively (Table 2). The minimum plant height (cm) (96.09) was recorded in control. The interaction between varieties and growth regulators levels showed the maximum plant height (cm) (178.67) in SURHAN-2012 x GA$_3$ 5 g ha^{-1}. The minimum plant height (cm) (77.05) was recorded in R00-100/6 among Brassica varieties.

Table 1. Days to maturity of canola genotypes as affected by foliar application of GA$_3$

Growth Regulators Levels	Genotypes				Mean for Growth Regulators Levels
	R00-100/6	**R00-125/12**	**SURHRAN-2012**	**Rainbow (P)**	
Control	112.65	110.67	108.68	111.33	110.83 A
GA$_3$ 4 g ha^{-1} (foliar application)	109.31	107.67	106.00	108.00	107.74 B
GA$_3$ 5 g ha^{-1} (foliar application)	105.25	101.67	101.33	105.00	103.40 D
GA$_3$ 6 g ha^{-1} (foliar application)	106.33	105.00	103.00	103.33	104.41 C
Mean for genotypes	108.39 A	106.25 C	104.75 D	106.99 B	---

Table 2. Plant heights (cm) of canola genotypes as affected by foliar application of GA$_3$

Growth Regulators Levels	Genotypes				Mean for Growth Regulators Levels
	R00-100/6	**R00-125/12**	**SURHRAN-2012**	**Rainbow (P)**	
Control	77.05	89.33	135.67	82.33	96.09 D
GA$_3$ 4 g ha^{-1} (foliar application)	83.67	119.00	168.00	129.67	125.08C
GA$_3$ 5 g ha^{-1} (foliar application)	89.33	135.67	178.67	133.33	134.25 A
GA$_3$ 6 g ha^{-1} (foliar application)	84.67	137.67	168.67	125.00	129.00 B
Mean for genotypes	83.68C	120.41BC	162.75A	124.83B	---

3.3 Branches per plant

The statistical analysis of variance for this character indicated significant differences among canola genotypes along with treatments. The results revealed that maximum branches per plant (10.33) were observed in SURHRAN-2012, followed by (7.21) and (6.35) in genotypes R00-125/12 and R00-100/6, respectively. The minimum branches plant^{-1} (5.49) were observed in Rainbow (P). In case of growth regulators levels, maximum branches per plant (8.33) were recorded with the application of GA$_3$ 5 g ha^{-1}, followed by (7.55) GA$_3$ 6 g ha^{-1} and (7.41) GA$_3$ 4 g ha^{-1}, respectively (Table 3). The minimum branches per plant (6.10) were verified in control. The collaboration between varieties and growth regulators levels showed maximum branches per plant (10.33) in SURHRAN-2012 x GA$_3$ 5 g ha^{-1} and the minimum plant height (5.49) in Rainbow (P) x control.

Table 3. Branches plant^{1} of canola genotypes as affected by foliar application of GA$_3$

Growth Regulators Levels	Genotypes				Mean for Growth Regulators Levels
	R00-100/6	R00-125/12	SURHRAN-2012	Rainbow (P)	
Control	5.66	5.43	9.00	4.33	6.10 D
GA$_3$ 4 g ha^{-1} (foliar application)	6.00	7.33	10.66	5.66	7.41 C
GA$_3$ 5 g ha^{-1} (foliar application)	7.66	8.33	11.00	6.33	8.33 A
GA$_3$ 6 g ha^{-1} (foliar application)	6.11	7.77	10.66	5.66	7.55 B
Mean for genotypes	6.35 C	7.21 B	10.33 A	5.49 D	---

3.4 Siliquae per plant

The statistical analysis of variance for this character indicated significant differences among canola genotypes along with treatments. The results revealed that the maximum siliquae per plant (362.24) was observed in SURHRAN-2012, followed by (260.66) and (245.91) in varieties Rainbow (P) and R00-125/12, respectively. The minimum siliquae per plant (181.58) was recorded in genotype R00-100/6. In case of growth regulators levels, the maximum siliquae per plant (291.24) was noted with the application of GA$_3$ 5 g ha^{-1}, followed by (287.33) and (278.24) with the application of GA$_3$ 6 g ha^{-1} and GA$_3$ 4 g ha^{-1}, respectively (Table 4). However, the minimum siliquae per plant (193.08) was recorded in control. The communication between the varieties and growth regulators levels showed the maximum siliquae per plant (362.24) in SURHRAN-2012 x GA$_3$ 5 g ha^{-1} and the minimum siliquae per plant (181.58) in R00-100/6 x control.

Table 4. Siliquae per plant of canola genotypes as affected by foliar application of GA_3

Growth Regulators Levels	Genotypes				Mean for Growth Regulators Levels
	R00-100/6	R00-125/12	SURHRAN-2012	Rainbow (P)	
Control	145.33	166.67	280.33	180.00	193.08 D
GA_3 4 g ha^{-1} (foliar application)	182.33	264.33	382.00	286.33	278.74 C
GA_3 5 g ha^{-1} (foliar application)	205.33	274.33	397.33	288.00	291.24 A
GA_3 6 g ha^{-1} (foliar application)	193.33	278.33	389.33	288.33	287.33 B
Mean for genotypes	181.58 D	245.91 C	362.24 A	260.66 B	---

3.5 Siliqua Length (cm)

The statistical analysis of variance for this character indicated significant differences among canola genotypes along with treatments. The results revealed that the maximum siliqua length (7.39 cm) was observed in SURHRAN-2012, followed by (6.48 cm) and (5.72 cm) in Rainbow (P) and R00-125/12, respectively. The minimum siliqua length (5.68 cm) was observed in R00-100/6. In case of growth regulators levels, the maximum siliqua length (7.23 cm) was marked in GA_3 5 g ha^{-1}, followed by (6.03) and (6.02) in GA_3 6 g ha^{-1} and GA_3 4 g ha^{-1}, respectively. The minimum siliqua length (5.97 cm) was registered in control (Table 5). The interaction between varieties and growth regulators levels showed the maximum siliqua length (7.39 cm) in SURHRAN-2012 x GA_3 5 g ha^{-1} and the minimum siliquae $plant^{-1}$ (5.68 cm) in R00-100/6 x control.

Table 5. Siliqua length (cm) of canola genotypes as affected by foliar application GA_3

Growth Regulators Levels	Genotypes				Mean for Growth Regulators Levels
	R00-100/6	R00-125/12	SURHRAN-2012	Rainbow (P)	
Control	5.83	5.13	6.70	6.23	5.97 D
GA_3 4 g ha^{-1} (foliar application)	5.33	5.22	7.33	6.23	6.02 C
GA_3 5 g ha^{-1} (foliar application)	6.43	7.20	8.66	6.66	7.23 A
GA_3 6 g ha^{-1} (foliar application)	5.13	5.33	6.88	6.80	6.03 B
Mean for genotypes	5.68 D	5.72 C	7.39 A	6.48 B	---

3.6 Seeds per siliqua

The statistical analysis of variance for this character indicated significant differences among canola genotypes along with treatments. The results revealed that the maximum seeds per siliqua (21.49) were observed in SURHRAN-2012, followed by (18.16) and (15.99) in Rainbow (P) and R00-125/12, respectively. The minimum seeds per siliqua (15.33) were observed in R00-100/6. In case of the growth regulators levels, the maximum seeds per siliqua (21.24) were recorded in GA$_3$ 5 g ha^{-1}, followed by (17.99) and (16.83) with the application of GA$_3$ 6 g ha^{-1} and GA$_3$ 4 g ha^{-1}, respectively. The minimum seeds per siliqua (14.83) were observed in control (Table 6). The interaction of varieties and growth regulators levels showed that the maximum seeds siliqua^{-1} (21.49) were recorded in SURHRAN-2012 x GA$_3$ 5 g ha^{-1}. The minimum sliqua plant^{-1} (15.33) was recorded in genotype R00-100/6 x control.

Table 6. Seeds per siliqua of canola genotypes as affected by foliar application of GA$_3$

Growth Regulators Levels	Genotypes				Mean for Growth Regulators Levels
	R00-100/6	R00-125/12	SURHRAN-2012	Rainbow (P)	
Control	13.66	15.00	14.33	16.33	14.83D
GA$_3$ 4 g ha^{-1} (foliar application)	14.33	17.00	20.00	16.00	16.83C
GA$_3$ 5 g ha^{-1} (foliar application)	17.00	17.66	29.33	21.00	21.24A
GA$_3$ 6 g ha^{-1} (foliar application)	16.33	14.33	22.33	19.00	17.99B
Mean for genotypes	15.33C	15.99C	21.49A	18.16B	---

3.7 Seed Index (1000 seed weight, g)

The statistical analysis of variance for this character indicated significant differences among canola genotypes along with treatments. The results revealed that the maximum seed index (4.50 g) was observed in SURHRAN-2012, followed by (4.30 g) and (4.02 g) in Rainbow (P) and R00-100/6, respectively. The minimum seed index (3.5 g) was observed in genotype R00-125/12. In case of growth regulators levels, the maximum seed index (4.34) was recorded with the application of GA$_3$ 5 g ha^{-1}, followed by (4.10 g) and (4.09 g) with the application of GA$_3$ 6 g ha^{-1} and GA$_3$ 4 g ha^{-1}, respectively. The minimum seed index (3.93 g) was observed in control (Table 7). The interaction between the varieties and growth regulators levels showed the maximum seed index (4.50 g) in SURHRAN-2012 x GA$_3$ 5 g ha^{-1}and the minimum seed index (3.52 g) in genotype R00-125/12 x control. Seed index (1000 seed weight) of genotype was enhanced for the foliar application of GA$_3$.

Table 7. Seed index of canola genotypes as affected by foliar application of GA_3

Growth Regulators Levels	Genotypes				Mean for Growth Regulators Levels
	R00-100/6	R00-125/12	SURHRAN-2012	Rainbow (P)	
Control	4.02	3.50	4.19	4.00	3.93 D
GA_3 4 g ha^{-1} (foliar application)	4.02	3.57	4.61	4.16	4.09 C
GA_3 5 g ha^{-1} (foliar application)	4.02	4.54	4.39	4.42	4.34 A
GA_3 6 g ha^{-1} (foliar application)	4.22	3.48	4.50	4.21	4.10 B
Mean for genotypes	4.02 C	3.52 D	4.50 A	4.30 B	---

3.8 Seed Yield (kg ha^{-1})

The statistical analysis of variance for this character indicated significant differences among canola genotypes along with treatments. The results revealed that the maximum seed yield (1443.08 kg ha^{-1}) was observed in SURHRAN-2012, followed by (1378.91 kg ha^{-1}) and (1375.58 kg ha^{-1}) in genotypes R00-125/12 and Rainbow (P), respectively. The minimum seed yield (1286.66 kg ha^{-1}) was observed in the variety R00-100/6 (Table 8). In case of growth regulators levels, the maximum seed yield (1416.83 kg ha^{-1}) was recorded with the application of GA_3 5 g ha^{-1}, followed by (1407.58 kg ha^{-1}) and (1375.75 kg ha^{-1}) with the application of GA_3 6 g ha^{-1} and GA_3 4 g ha^{-1}, respectively. The minimum seed yield (1266.08 kg ha^{-1}) was recorded in control. The interaction between the varieties and growth regulators levels showed the maximum seed yield (1443.08 kg ha^{-1}) in SURHRAN-2012 x GA_3 5 g $ha^{-1}$and the minimum seed yield (1286.66 kg ha^{-1}) in genotype R00-100/6 x control.

Table 8. Seed yield (kg ha^{-1}) of canola genotypes as affected by foliar application of GA_3

Growth Regulators Levels	Genotypes				Mean for Growth Regulators Levels
	R00-100/6	R00-125/12	SURHRAN-2012	Rainbow (P)	
Control	1221.67	1351.00	1128.00	1363.67	1266.08D
GA_3 4 g ha^{-1} (foliar application)	1245.00	1375.67	1504.00	1378.33	1375.75 C
GA_3 5 g ha^{-1} (foliar application)	1348.33	1400.33	1580.33	1338.33	1416.83 A
GA_3 6 g ha^{-1} (foliar application)	1331.67	1388.67	1560.00	1350.00	1407.58 B
Mean for genotypes	1286.66 D	1378.91 B	1443.08 A	1357.58 C	---

4. Discussion

A wide range of studies have indicated that GA_3 promotes growth, flowering, early maturity and high yield in plants [18]. On the other hand, Urbanova and Leubner-Metzger and Oh and Kim [19, 20] reported that it exhibits several desirable and beneficial effects in the form of seed germination, as well as leaf expansion and development in different crops. The effects of GA on stem elongation were elaborated by Oh et al. and Dong et al. [21, 22]. Alshakhaly and Qrunfleh and Sumanasiri et al. [23, 24] manifested its positive effects in terms of early flowering which is very beneficial, while its good results for fruit development were presented by Bergmann et al. and Toscano et al. [25, 26]. A significant increase in plant height was induced by different levels of GA_3. Cornea-Cipcigan et al. and Siddiqui et al. [27, 28] suggested that GA, as a spontaneous phytoregulator, can be utilized in a variety of ways in the field of agriculture, owing to its advantageous impacts on the growth and development of crops. Blanchard et al. [29] postulated that phytohormones participate actively in plant growth and its life processes. Runkle and Blanchard and Runkle [30, 31] stated that GA is very active for increasing primary growth when it is mixed with cytokinin.

The number of branches per plant varies with the combined effect of genetic makeup and environmental conditions. This might be due to the maximum division of cells and their elongation corresponding with the increase in photosynthetic activity and better accumulation of food [32, 33]. Miceli et al and Kandil [34, 35] demonstrated that, for the enhancement of productivity and phenotypic attributes in crops, GA is practiced rigorously. Being a bioregulator, it is quite friendly to the surroundings. Some experiments manifested that the transmission of assimilates to sex organs due to the presence of GA_3 might improve, which can benefit the increase of siliquae per plant. Similar results were reached by Uddin et al. and Soliman [36, 37]. Bultynck and Lambers [38] found a lot of factors, including external and internal factors, responsible for low cell growth. Among these factors, bioregulators are the most essential internal factors.

El-Khourya et al. [39] suggested that it is very useful in commercial horticulture for the betterment of plant growth and yields. They further added that effective cell growth and cell elongation are caused by GA effects on stem and root growth. Nizamani et al. [40] said that sustainable improvement of yield has been a big challenge for plant breeders in order to secure food in the upcoming years, in which fertilization is a very critical challenge. George et al. [41] explained that GA might have participated in the formulation of seeds and a greater number of seeds are produced in pods when their nourishment is normal. However, when their nourishment is abnormal then more aborted seeds appear. For the modification of crop plants both natural and artificial phytohormones are used in agriculture, so that better and the most useful cultivation of plants can be put into practice [42]**.**

Mir et al. found similar results for seed index [43]. Moreover, many studies have revealed that GA_3 plays an important role in enhancing seed quality. According to Hedden and Sponsel [44], GA is one of the most vital endogenous hormones in plants because they develop plant body through the regulation of many physiological mechanisms. They are not only able to modify seed germination but also dormancy [45]. Harkess and Lyons [46] also arrived at the same results of enhancement in seed yield when they exogenously applied GA_3. Mir et al. and Akhtar et al. [47, 48] notified that these hormones are present when the transcription of those genes is induced which function for cell elongation and cell division.

5. Conclusion

It is concluded that growth and regulators levels play a significant role in all the growth and yield parameters of canola crop. The results also proved that the variety SURHRAN-2012 performed better in all experiments. It is suggested from the current findings that the variety SURHRAN-2012 x GA_3 5 g ha^{-1} (foliar application) is a suitable combination for getting maximum yield.

Conflict of Interest

The authors declare no conflict of interest.

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