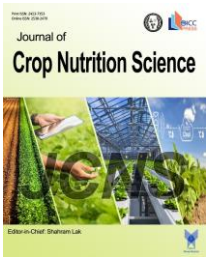

J. Crop Nutr. Sci. 2025; 11(1):Article 3

Journal of Crop Nutrition Science (JCNS)

https://doi.org/10.57647/jcns.2025.1101.03

Research Article

Evaluation Physiological Parameters of Canola (*Brassica napus* L.) Affected Different Concentration and Stage of Use Gibberellic acid under Warm and Dry Climate Condition (Southwest of Iran)

Somayeh Ghalandari[1,2], Tayeb Sakinejad[*2], Mani Mojaddam[2], Shahram Lak[2], Mojtaba Alavi Fazel[3]

[1] *Department of Agronomy, Khuzestan Science and Research Branch, Islamic Azad University, Ahvaz, Iran*
[2] *Department of Agronomy, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran*
[3] *Department of Agronomy, Science and Research Branch, Islamic Azad University, Tehran, Iran*

***Corresponding author:** t.saki1350@yahoo.com

Article History:

Received:
28 December 2024

Revised:
29 January 2025

Accepted:
1 March 2025

Published in Issue:
31 March 2025

Abstract

Background: Growth regulators play an essential role in the biosynthesis of crop fibres, affecting both the elongation rate and quality. Gibberellic acid (GA3) is a phytohormone that is needed in small quantities at low concentration to accelerate plant growth and development.

Objectives: Current study was done to assess response of grain yield, its components, morphological and qualitative traits of canola genotypes to apply different time and concentration of growth regulator hormone (gibberellic acid).

Methods: This research was done via combined analysis split plot factorial experiment based on randomized complete blocks design with three replications. The main factor included different level of canola genotypes (Hyola401, RGS003, Jerry) and sub factors consisted different concentration of gibberellic acid (0, 50 and 100 mg.l^{-1}) and several time of application of gibberellic hormone (at before planting grain treatment, vegetative phase before flowering, flowering before pod emergence).

Result: According result of analysis of variance effect of genotype, different concentration and time of application of gibberellic hormone on all measured traits (instead Chlorophyll) was significant at 5% probability level but interaction effect of treatments was not significant. The highest and lowest amount of all measured traits between genotypes was for Hyola 401 and Jerry, respectively. Assess mean comparison result of application different concentration of gibberellic hormone indicated the maximum amount of number of pod per plant (97.31), number of grain per pod (18.71), 1000 grain weight (2.89 gr), grain yield (2575 kg.ha^{-1}), Biological yield (7620 kg.ha^{-1}), harvest index (33.79%), oil content (46.42%), oil yield (1192.51 kg.ha^{-1}), Cata-lase enzyme (21.65 unit/mg protein) and Peroxidase enzyme (17.89 unit.mg protein^{-1}) were noted for 100 ppm gibberellic and minimum amount of those traits belonged to control. Compare different time of application of gibberellic hormone revealed the highest and lowest amount of all measured traits (instead protein content and protein yield) were for vegetative phase before flowering stage and Flowering before pod emergence, respectively.

Conclusion: According result of current study advised to use Hyola401 hybrid with 100 ppm gibberellic hormone at VPBF growth stage to achieve maximum crop production by farmers.

Keyword: Antioxidant enzyme, Chlorophyll, Crop production, Growth regulator, Hormone.

Cite this article: Ghalandari, S., Sakinejad, T., Mojaddam, M., Lak, S. & Alavi Fazel, M., (2025). *Journal of Crop Nutrition Science,* Evaluation Physiological Parameters of Canola (*Brassica napus* L.) Affected Different Concentration and Stage of Use Gibberellic acid under Warm and Dry Climate Condition (Southwest of Iran), *11(1),* Article 3. https://doi.org/10.57647/jcns.2025.1101.03

1. Background

Plant growth regulators are known to enhance the source sink relationship and stimulate the translocation of photo assimilates thereby helping in effective flower formation, fruit and grain development and ultimately enhance productivity of the crop. Growth regulators can improve the physiological efficiency including photosynthetic ability and can enhance the effective partitioning of accumulates from source to sink in the field crops (Basuchaudhuri, 2016). Growth regulators play an essential role in the biosynthesis of crop fibers, affecting both the elongation rate and quality. The gibberellic (GA) are natural plant growth promoting hormones that cause the elongation of plant cells. Exogenous application of GA alters plant growth and affects developmental features (Ullah et al., 2017). Gibberellic acid (GA3) is an endogenous growth regulator in plants that plays an important role in plant cell growth and elongation (Zang et al., 2016). Plant growth regulators play a central part in plant life. Plant hormones can help to manage equilibrium of phytohormones. Gibberellic being known well as plant growth promoting hormone have shown to be involved in a variety of plant growth and development (Buriro et al., 2022). Gibberellic acid has been indicated to be effective in improving overall plant growth and yield of some crops, although, its effectiveness depends on the concentration and timing of application, also environmental situations (Vekaria et al., 2017). Gibberellic has great role in balancing the growth of internodes, growth and development of leaves and led to produce rapid vegetative growth in leafy vegetable crops and grain feed (Fadhil and Almasoody, 2019). Gibberellic, (GAs) a group of diterpenoid plant hormones, have an important role in regulation of diverse developmental processes in plants such as grain germination, cell and organ elongation as well as flowering and have wide applications in modern agriculture (Taiz and Zeiger, 2010). Basuchaudhuri (2016) reported soaking the grain with Gibberellic with a concentration of 10 ppm before graining then spraying with the same substance during the vegetative and flowering stages was proven to give the highest yield producing 2.62 $t.ha^{-1}$ which has a significant difference over the control which was 1.72 $t.ha^{-1}$. GA3 is a crop hormone that can improve grain germination and seedling growth of plants (Tsegay and Andargie, 2018). Sarkar et al. (2002) reported by sprayed at three different times with two concentrations (100 and 200 ppm) of Gibberellic, at 100 ppm in soybean crop had regulatory led to increase the plant height, number of branches, number of leaves, leaf area per plant, number of flowers, number of pods, percentage of fruit set, number of grains per plant, grain yield per plant, 1000 grain weight and grain yield. Akter et al. (2007) reported grain yield per plant had significant positive correlation with effective traits on crop production such as plant height, number of grains per pod, number of fertile pod per plant, percent sets of pod per plant. Singh et al. (2017) reported primed the grains by GA3 which is the most important growth regulator used for grain germination, mobilization of food in grain storage cell, cell elongation, permeability of cell membrane, apical bud dormancy, flowering and fruiting growth. GA3 application led to improve the translocation of assimilates to the vegetative organ which affected in the highest of plant height, number of tillers $hill^{-1}$ (Pepi et al., 2014). Gibberellics are a large family of crop hormones which are bioactive growth regulators, controlling grain germination, stem elongation, flowering, pod setting and pod size. For this reason, gibberellic acid was used in different application time in some research. Among the gibberellics the most predominant is gibberellic acid (gibberellic A3 or GA3), because of its frequent and high level occurrence in microbial fermentations as well as its high Biologicalal activity in plants (Bruckner and Blechschmidt, 1991). Ghodrat et al (2012) reported Gibberellic stimulate rapid stem and root growth, induce mitotic division in the leaves of some crop, and improve grain germination so as a result increase in plant height was behold. Gibberellic acid in plants found on signal transduction pathways leading to elongation of plant vegetative parts. GA3 promotes cell elongation through releasing DELLA mediated inhibition of BZR1 transcription factor which increase plant height (He and Li, 2013).

2. Objectives

This study was done to assess response of grain yield, its components, morphological and qualitative traits of canola genotypes to apply different time and concentration of growth regulator hormone (Gibberellic acid).

3. Materials and methods

3.1. Field and Treatments Information

This research was carried out to evaluate effect of different concentration and time of application of gibberellic hormone on canola genotypes production via combined analysis split plot factorial experiment based on randomized complete blocks design with three replications along two agronomic years (2015-16 and 2016-17). Place of research was located in Ahvaz city at longitude 48°40'E and latitude 31°20'N in Khuzestan province (Southwest of Iran). The main factor included different canola genotype (Hyola401, RGS003, Jerry) and sub factors consisted different concentration of gibberellic hormone (0, 50 and 100 $mg.l^{-1}$) and different time of application of gibberellic hormone [Planting, vegetative phase before flowering

10.57647/jcns.2025.1101.03

(VPBF), flowering before pod emergence (FBPE)]. This experiment had 27 plots. Each plot consisted of 8 lines with a distance of 30 cm and 5 meters' length. The distance between the shrubs on every row was 5 cm.

3.2. Farm Management

Base fertilizers (50 kg.ha^{-1} Nitrogen from urea, 100 kg.ha^{-1} phosphorus from ammonium phosphate and 100 kg.ha^{-1} potassium from potassium sulfate) were added to the soil based on soil tests and the recommendations of the Iranian Soil and Water Research Institute at the planting stage. Also 100 kg.ha^{-1} Nitrogen was added to the soil at stem elongation phase. The light disk harrow was used to mix the soil and the fertilizer after soil fertilization. The furrows were covered with soil. The grains were planted 3 cm above the fertilizer. Physical and chemical properties of the soil are mentioned in table 1. To apply the first stage of gibberellic hormone before planting the grains were soaked in three concentrations of the hormone overnight. The second stage of gibberellic application was done in the vegetative growth stage before flowering. The last stage of gibberellic application was done during the flowering to pod emergence stage.

3.3. Measured Traits

In order to determine the yield components during physiologic maturity, 10 plants were chosen randomly from each plot. Then 1000 grain weight, number of pod per plant and number of grain per pod were assessed. In final harvest area, one square meter of each plot, grain yield was calculated. In addition, grain samples were dried, weighed and analyzed for oil content. Oil content determine by Near Infrared Spectroscopy (Sato, 2002). Results for oil content expressed on 8.5 % moisture. Oil yield calculated by multiplying grain yield by oil content. Kjeldahl method was used to determine the amount of plant nitrogen content. Finally, nitrogen percentage was calculated as follow (Sosulski and Imafidon, 1990): Equ. 1. Protein content= Nitrogen percentage×5.7. Protein yield calculated by multiplying grain yield by protein content. Harvest index (HI) was calculated according to formula of Gardner et al. (1985) as follows: Eq.2. HI= (Grain yield/Biological yield) ×100. In order to determine the amount of antioxidant enzymes, all samples taken from the leaves of plants treated with gibberellic were frozen in liquid nitrogen and were kept at -85°C until the time of measurement. Catalase and ascorbate peroxidase enzymes, they were measured at 25°C by spectrophotometric method by Janda et al. (1999) methods respectively with wavelengths of 240 and 290 nm. The amount of protein was measured according Bradford method. For this purpose, 1 ml of Bradford's solution along with 155 microliters of enzyme extract was placed in the spectrometer after complete mixing and the absorbance of the solution was recorded at 595 nm wavelength. The protein concentration was calculated in mg.g^{-1} of fresh tissue by using standard curve (Bradford, 1976).

3.4. Farm Management

Analysis of variance was done via SAS (Ver.8) software. Mean comparison was done with Duncan test at 5% probability level.

4. Results and discussion

4.1. Number of Pod Per Plant (NPPP)

The results of analysis of variance revealed a significant difference between several genotype, concentration and time of application of gibberellic hormone in terms of the effect on the NPPP ($p < 0.05$) (Table 2). Mean comparison result of different concentration of gibberellic showed the maximum NPPP (97.31) was observed in 100ppm and the lowest one (71.91) was found in control treatments, also among different genotypes maximum of mentioned traits (99.9) was obtained for Hyola401 and minimum of that (73.9) was for Jerry (Table 3). Soliman (2019) reported transmission of assimilates into sex organs due to apply gibberellic hormone might have improved by benefit the increase of pod per plant. Compare different growth stage due to apply gibberellic showed VPBF had the highest amount of NPPP and lowest one was for FBPE stage (Table 3). GA3 might have increased the translocation of as similates to the reproductive organ which resulted in the maximum number of siliqua plant^{-1} up to certain levels of GA3 application (Uddin et al., 1986). Some experiment manifested that transmission of assimilates to the sex organs due to the presence of GA3 might have improved which can benefit the increase of siliquae per plant (Soliman, 2019).

Table 1. Physical and chemical properties of studied field

Soil depth (cm)	Acidity (pH)	Electrical conductivity (ds.m^{-1})	Organic carbon (%)	Absorbable Phosphorus (ppm)	Absorbable potassium (ppm)
0-30	7.76	7.55	0.55	9.11	184
Clay (%)	Silt (%)	Sand (%)	Soil texture	ρ_b (gr.cm^{-3})	Fe (ppm)
33	37	30	Clay	1.29	10.4

10.57647/jcns.2025.1101.03

4.2. Number of Grain Per Pod (NGPP)

According result of analysis of variance effect of genotype, different concentration and time of application of gibberellic hormone on NGPP was significant at 5% probability level but interaction effect of treatments was not significant (Table 2). The highest and lowest NGPP between genotypes was for Hyola401 (19.5) and Jerry (15.3), respectively (Table 3). NGPP varied from 18.71 to 14.61 among the different concentration treatments. The highest average NGPP was observed in 100ppm treatment as 18.71, and the lowest one was found in control treatment as 14.61 (Table 3). The plant growth regulators same GA3 might be involved in formation of grains in the pods and their optimum nutrition have resulted in less number of aborted grains and thus maximized the permanence of fertile grains/pod in rapes (Akter et al., 2007). George et al. (2008) reported that gibberellic might have cooperated in the formulation of grains and more number of grain is produced in pods when their nutrition normal, but if it is abnormal more aborted grains led to produce. Using gibberellic at VPBF stage led to produce highest amount of NGPP in compare another growth stage (Table 3). Khan et al. (1998) stated that foliar application of gibberellic acid at the preflowering stage of mustard crop led to 35.5 % increase in leaf area, followed by improve trapping of sunlight, which clearly boost dry matter. Boultior and Morgan (1992) reported that plant growth regulators such as GA3 might be involved in formation of grains in the pod and their optimum nutrient led to less number of aborted grains and so maximized the remain NSPP in rapes and mustard.

4.3. 1000 grain weight (GW)

The results demonstrated that there was a significant difference between different levels of genotype, several concentration and time of application of gibberellic hormone in terms of their effect on the GW of canola at $p < 0.05$ probability level (Table 2). Compare genotypes indicated the highest GW was observed in Hyola401 treatment as 3.33 g, and the lowest one was found in Jerry as 2.73 g (Table 3). Riley (1987) Gibberellic can stimulate rapid stem and root growth, induce mitotic division in the leaves of some plants, and increase grain germination. Mean comparison different gibberellic concentration revealed significant increase about 17.84 and 35.68% by using 50 and 100 ppm in compare to control, respectively (Table 3). Thuc et al. (2021) reported by increasing the concentration of GA3 to 50, 75, 100 and 150 ppm further led to improve the weight of grains per pod and was statistically significant difference at 1% from the control treatment. Between different growth stage of apply gibberellic hormone at VPBF stage had the maximum SW (3.01g) and lowest one (2.38g) belonged to FBPE stage (Table 3). Niknejhad and Pirdashti (2012) reported that preflowering GA3 application was increased crop production in rice. Tiwari et al. (2011) reported GA3 might be implicate in formation of grain filling and their optimum nutrition led to less number of aborted grains and so the highest survival of filled grains.

4.4. Grain yield (GY)

Variance analysis of data indicated all treatments significantly affected the GY ($p < 0.05$), but there was no significant difference between interaction effects of treatments (Table 2). Among different genotypes maximum of GY (2625 $kg.ha^{-1}$) was obtained for Hyola401 and minimum of that (2244 $kg.ha^{-1}$) was for Jerry (Table 3). The data indicated that the highest GY (2575 $kg.ha^{-1}$) obtained by 100ppm gibberellic. Control treatment (2196 $kg.ha^{-1}$) produced the lowest values. Application of gibberellic hormone (100 and 50ppm) significantly increased GY about 17.25% and 11.47 % compared to control, respectively (Table 3).

Agawane and Parhe (2015) reported grains primed with gibberellic at 100 ppm for 12 hours had significantly higher germination percentage over untreated control of soybean. The grain priming significantly influenced the GY and yield contributing characters of soybean cv. JS 9305 showing to the corresponding favorable improvement in NPPP, NGPP, test weight, GY and BY. Compare different growth stage due to apply gibberellic showed VPBF had the highest amount of GY and lowest one was for FBPE stage (Table 3). Uzun et al. (2012) stated that environmental conditions were affected flowering on chickpea and flowering was be earlier on arid conditions. Ramesh et al. (2019) reported foliar application of GA3 produced higher GY and its components due to improve supply of photosynthetic materials and its efficient mobilization in crop giving rise. Higher GY might be related due to better translocation of photosynthetic from source to sink (Bhatt and Singh, 1997). Lovato et al. (2000) reported that foliage spraying with 20 ppm GA3 before bolting induced a slight earliness in grain maturity and increased grain yield. George et al. (2008) explained that GA might have participated in the formulation of grains and a greater number of grain is produced in pods when their nourishment normal, but when their nourishment is abnormal more aborted grains come into being. For the modification of crop plants, both natural as well as artificial phytohormones are used in agriculture so that better and most useful cultivation of plants can be put into practice for unlike processes of development Wang et al. (2020).

Table 2. Result analysis of variance of measured traits

S.O.V	df	No. pod per plant	No. seed per pod	1000-seed weight	Seed yield	Biologic yield	Harvest index	Oil content
Year	1	15.198^{ns}	0.580^{ns}	0.212^{ns}	379.654^{ns}	717.191^{ns}	4.519^{ns}	3.590^{ns}
Replication × Year	4	18.903^{ns}	0.779^{ns}	0.321^{ns}	349.080^{ns}	633.673^{ns}	1.195^{ns}	2.374^{ns}
Genotype (G)	2	572.781*	57.989*	58.802*	9145.506*	11237.154*	64.771*	31.123*
G × Year	2	22.156^{ns}	0.970^{ns}	0.103^{ns}	310.025^{ns}	242.747^{ns}	2.534^{ns}	0.983^{ns}
Error I	8	35.112	1.887	2.231	871.756	945.145	2.812	3.453
Gibberellin Concentration (GC)	2	449.318*	46.329*	23.145*	7932.599*	9632.543*	39.097*	56.349*
GC × Year	2	12.551^{ns}	0.039^{ns}	0.603^{ns}	296.006^{ns}	153.321^{ns}	0.339^{ns}	0.069^{ns}
G × GC	4	11.154^{ns}	0.870^{ns}	0.909^{ns}	154.691^{ns}	227.599^{ns}	1.977^{ns}	0.007^{ns}
Year × G × GC	4	2.412^{ns}	0.118^{ns}	0.803^{ns}	202.710^{ns}	339.654^{ns}	0.572^{ns}	0.127^{ns}
Time of Gibberellin application (TGA)	2	337.957*	18.671*	18.614*	5944.340*	7999.247*	38.622*	49.052*
TGA × Year	2	8.550^{ns}	0.225^{ns}	0.701^{ns}	111.747^{ns}	278.840^{ns}	1.357^{ns}	0.090^{ns}
TGA × G	4	10.196^{ns}	0.366^{ns}	0.808^{ns}	254.015^{ns}	259.025^{ns}	1394^{ns}	0.734^{ns}
TGA × G × Year	4	13.466^{ns}	0.138^{ns}	0.601^{ns}	118.367^{ns}	211.673^{ns}	2.813^{ns}	0.044^{ns}
GC × TGA	4	7.691^{ns}	0.078^{ns}	0.044^{ns}	299.636^{ns}	321.052^{ns}	0.791^{ns}	0.079^{ns}
Year × GC × TGA	4	17.810^{ns}	0.423^{ns}	0.101^{ns}	250.877^{ns}	284.164^{ns}	3.988^{ns}	0.141^{ns}
G × GC × TGA	8	19.567^{ns}	0.259^{ns}	0.303^{ns}	230.770^{ns}	112.469^{ns}	0.966^{ns}	0.082^{ns}
Year× G × GC × TGA	8	21.348^{ns}	0.125^{ns}	0.551^{ns}	257.622^{ns}	356.275^{ns}	0.477^{ns}	0.137^{ns}
Error II	96	23.950	0.910	0.823^{ns}	327.142^{ns}	499.522	0.710	1.121
CV (%)	-	9.52	8.53	5.13	6.32	7.68	8.61	6.19

^{ns}, * and **: no significant, significant at 5% and 1% of probability level, respectively.

Continue of table 2.

S.O.V	df	Oil yield	Protein content	Protein yield	Chlorophyll content	Catalase enzyme	Peroxidase enzyme
Year	1	67.105^{ns}	5.289^{ns}	25.773^{ns}	0.284^{ns}	0.611^{ns}	0.599^{ns}
Replication × Year	4	86.744^{ns}	2.693^{ns}	32.322^{ns}	0.023^{ns}	0.795^{ns}	0.669^{ns}
Genotype (G)	2	819.553*	99.401*	429.723*	0.098^{ns}	67.121*	52.123*
G × Year	2	51.954^{ns}	1.214^{ns}	44.619^{ns}	0.851^{ns}	0.870^{ns}	0.769^{ns}
Error I	8	170.305	9.449	56.220	8.550	1.105	1.051
Gibberellin Concentration (GC)	2	499.917*	84.347*	290.224*	0.654^{ns}	44.225*	39.119*
GC × Year	2	78.332^{ns}	0.262^{ns}	16.112^{ns}	0.551^{ns}	0.035^{ns}	0.028^{ns}
G × GC	4	44.176^{ns}	0.070^{ns}	14.801^{ns}	0.426^{ns}	0.880^{ns}	0.699^{ns}
Year × G × GC	4	65.320^{ns}	0.220^{ns}	7.424^{ns}	0.331^{ns}	0.227^{ns}	0.198^{ns}
Time of Gibberellin application (TGA)	2	527.062*	79.837*	17.384*	9.611*	19.786*	15.171*
TGA × Year	2	84.148^{ns}	0.019^{ns}	8.669^{ns}	1.699^{ns}	0.331^{ns}	0.267^{ns}
TGA × G	4	39.814^{ns}	0.148^{ns}	6.882^{ns}	1.446^{ns}	0.399^{ns}	0.277^{ns}
TGA × G × Year	4	57.248^{ns}	1.030^{ns}	20.923^{ns}	1.592^{ns}	0.188^{ns}	0.165^{ns}
TGA × GC	4	61.211^{ns}	0.019^{ns}	18.260^{ns}	1.225^{ns}	0.094^{ns}	0.088^{ns}

^{ns}, * and **: no significant, significant at 5% and 1% of probability level, respectively.

Continue of table 2.

S.O.V	df	Oil yield	Protein content	Protein yield	Chlorophyll content	Catalase enzyme	Peroxidase enzyme
Year × GC × TGA	4	74.226^{ns}	0.017^{ns}	15.305^{ns}	1.197^{ns}	0.577^{ns}	0.321^{ns}
G × GC × TGA	8	35.143^{ns}	0.926^{ns}	11.747^{ns}	1.732^{ns}	0.361^{ns}	0.297^{ns}
Year× G × GC × TGA	8	70.552^{ns}	1.206^{ns}	9.051^{ns}	1.844^{ns}	0.287^{ns}	0.198^{ns}
Error II	96	85.033	3.136	29.275	6.99	0.899	0.736
CV (%)	-	8.58	7.65	9.89	5.69	7.89	6.57

^{ns}, * and **: no significant, significant at 5% and 1% of probability level, respectively.

4.5. Biological yield (BY)

Result of analysis of variance revealed effect of genotype, different concentration and time of application of gibberellic hormone on BY was significant at 5% probability level but interaction effect of treatments was not significant (Table 2). Hyola401 hybrid was achieved the highest amount of BY (7781 kg.ha^{-1}) and lowest one was for Jerry (7285 kg.ha^{-1}) (Table 3). Mean comparison result of different concentration of gibberellic revealed that the maximum and the minimum amount of BY belonged to 100ppm (7620 kg.ha^{-1}) and control (7170 kg.ha^{-1}). In other hand apply gibberellic hormone (50 ppm and 100 ppm) increased BY by 3.20 and 6.27% compared to none use of gibberellic (Table 3). Mean comparison also showed application gibberellic hormone at the VPBF produced the highest contents in compare another stages (Table 3). Ergin and Kayan (2021) reported the maximum flowering time was happening on 200 ppm application doses and the lowest amount was achieved at control. Upadhyay and Ranjan (2015) reported that application of GA3 (20 ppm) at bud initiation and 50% flowering of soybean increased the BY and SY along with test weight and HI.

Leilah and Khan (2021) reported Early spraying of GA3 leads to rapid leaf growth during the vegetative growth phase; therefore, photosynthesis production in the leaves achieves more than the basic needs of the plant, which leads to crop storing photosynthesis products, so increasing crop production. Alshakhaly and Qrunfleh (2018) reported its positive effects in early flowering stage which became very beneficial and its good results for crop production were presented by Bergmann et al. (2016).

4.6. Harvest indeex (HI)

Several genotype, different concentration and time of application of gibberellic hormone had significantly influenced the HI ($p < 0.05$) (Table 2). HI was the highest (33.73 cm) belonged to Hyola401 which was statistically similar with RGS003 and the lowest (30.80 cm) was found in the Jerry (Table 3). The highest HI was obtained with consumption rate of gibberellic 100 ppm (however, there were not significant differences between 100 and 50ppm) and the lowest was in control. This indicates that HI was increased with consumption of 100 ppm relative to control as 10.35% (Table 3). It seems might be due to GA3 application accelerated photosynthetic activity and translocation of photosynthates to sink, which leads to recorded higher HI. The higher HI indicated that GA3 application accelerated assimilate supply to sink, which is in agreement with the results of Gouping and Etmal (1993). GA3 at 0-75 mg.l^{-1} applied at 600 L.ha^{-1} at the pre flowering stage on Indian mustard (Brassica Juncea) was reported to increase the HI (Khan, 1997).

4.7. Oil content (OC)

Result of analysis of variance revealed effect of genotype, different concentration and time of application of gibberellic hormone on OC was significant at 5% probability level but interaction effect of treatments was not significant (Table 2). At Hyola401, greatest OC was recorded (46.58%) and this was significantly ($p<0.05$) higher than the RGS003 and Jerry, respectively (44.72%, 43.81%) (Table 3). Maximum OC (46.42%) was recorded with the 100ppm gibberellic and the minimum of that (43.54%) was recorded from the control (Table 3). GA3 is led to help improve the OC in sesame grains (Behera et al., 2017) in same direction, Thuc et al. (2021) reported the treatment applied GA3 with concentrations of 100 and 150 ppm had the highest OC in sesame grains, respectively 49.2 and 49%, which is significant difference from the control treatment did not apply GA3. Compare different growth stage due to apply gibberellic showed VPBF had highest amount of OC and lowest one was for FBPE stage (Table 3).

Table 3. Mean comparison effect of genotypes, Gibberellin concentration and time of gibberellin application on studied traits

Treatment	No. pod per plant	No. seed per pod	1000-seed weight (gr)	Grain yield (kg.ha^{-1})	Biologic yield (kg.ha^{-1})	Harvest index (%)
Genotype						
Hyola401	99.9a*	19.5a	3.33a	2625a	7781a	33.73a
RGS003	84.3b	17.2b	3.09ab	2498b	7515b	33.24a
Jerry	73.9c	15.3c	2.73b	2244c	7285c	30.80b
Gibberellin concentration (ppm)						
Control	71.91c	14.61c	2.13b	2196c	7170c	30.62b
50	82.83b	16.39b	2.51ab	2448b	7400b	33.08a
100	97.31a	18.71a	2.89a	2575a	7620a	33.79a
Time of gibberellin application						
Seed treatment	79.2b	15.61b	2.77ab	2399b	7302b	32.85ab
vegetative phase before flowering	94.7a	17.95a	3.01a	2520a	7510a	33.55a
Flowering before pod emergence	69.5c	13.82c	2.38b	2152c	7050c	30.52b

*Similar letters in each column show non-significant difference at 5% probability level via Duncan test.

Continue of table 3.

Treatment	Oil content (%)	Oil yield (kg.ha^{-1})	Protein content (%)	Protein yield (kg.ha^{-1})	Chlorophyll content (Spad)	Catalase enzyme (unit/mg protein)	Peroxidase enzyme (unit/mg protein)
Genotype							
Hyola401	46.58a*	1231.62a	24.73c	649.25c	43a	19.91a	16.87a
RGS003	44.72ab	1115.90b	26.82b	669.89b	42a	16.22b	12.89b
Jerry	43.81b	981.99c	30.65a	687.82a	41a	12.70c	9.11c
Gibberellin Concentration (ppm)							
Control	43.54b	955.83c	30.44a	668.55a	39a	9.71b	11.98b
50	44.51ab	1088.55b	26.55b	649.85b	40a	19.88ab	15.96ab
100	46.42a	1192.51a	24.49c	630.72c	38a	21.65a	17.89a
Time of gibberellin application							
Seed treatment	44.15ab	1060.15b	26.14ab	627.11b	40ab	21.88ab	16.11ab
vegetative phase before flowering	46.12a	1164.22a	24.11b	607.66c	44a	23.61a	18.05a
Flowering before pod emergence	43.11b	928.72c	30.21a	650.33a	38b	13.55b	10.55b

*Similar letters in each column show non-significant difference at 5% probability level via Duncan test.

10.57647/jcns.2025.1101.03

4.8. Oil Yield (OY)

According result of analysis of variance effect of genotype, different concentration and time of application of gibberellic hormone on OY was significant at 5% probability level but interaction effect of treatments was not significant (Table 2). The highest value was obtained in Hyola401 (1231.62 kg.ha^{-1}) and the least was found in Jerry (981.99 kg.ha^{-1}) (Table 3). Highest OY (1192.51 kg.ha^{-1}) was recorded with the application of 100ppm gibberellic and lowest one (955.83 kg.ha^{-1}) was for control (Table 3). Baydar (2000) stated oil content improved significantly from 33.8 % to 38.8 % with the using of 300 ppm GA3 at the budding stage. Also Bibi et al. (2003) reported that increasing concentrations of GA3 gradually improved OC of Sunflower. Also Nizamani et al (2018) reported similar result.

4.9. Protein Content (PC)

Result of analysis of variance revealed effect of genotype, different concentration and time of application of gibberellic hormone on PC was significant at 5% probability level but interaction effect of treatments was not significant (Table 2). Among different genotypes maximum of PC (30.65%) was obtained for Jerry and minimum of that (24.73%) was for Hyola401 (Table 3). Compare different level of gibberellic concentration showed the highest value of PC (24.49%) was recorded with the effect of nonuse gibberellic and lower one (30.44%) belonged to 100ppm (Table 3). Mean comparison also showed application gibberellic hormone at the FBPE produced the highest contents in compare another stages (Table 3). Similar results for grain index were in conformity with Mir et al. (2009). Moreover, many studies have shown that GA3 plays an important role in grain quality. According to Hedden and Sponsel (2015), GA is one of the most vital endogenous hormones in plants, because they bring development in the body of a plant for the regulation of lots of physiological mechanisms.

4.10. Protein Yield (PY)

According result of analysis of variance effect of genotype, different concentration and time of application of gibberellic hormone on PY was significant at 5% probability level but interaction effect of treatments was not significant (Table 2). Among genotypes highest value obtained in variety Jerry (687.82 kg.ha^{-1}) and least in Hyola401 i.e 649.25 kg.ha^{-1} (Table 3). Hafeez et al. (2018) reported plant hormones such as gibberellic led to a change, release or probably production of regulator protein and as a result, the active form of this protein is only found in Aleurone cells which have received the hormonal message. Plant hormones such as gibberellic led to a change, release or probably production of regulator protein and as a result, the active form of this protein is only found in Aleurone cells which have received the hormonal message (Takahashi et al., 1991).

4.11. Chlorophyll content (CC)

Gibberellic Acid regulators increase the strength of physiological source by increasing chlorophyll and effective age of leaves which finally lead to the increase of grain yield per area (Ghodrat et al., 2012). There was only significant difference between times of application of gibberellic hormone treatments on CC ($p < 0.05$) in compare to another factor (Table 2). Between different growth stages, apply gibberellic hormone at VPBF stage had the maximum CC (44 Spad) and lowest one (38 Spad) belonged to FBPE (Table 3). Thuc et al. (2021) reported there was nonsignificant difference in chlorophyll trait between GA3 supplementation treatments with concentrations of 50, 75, 100 and 150 ppm. Gibberellic is a great factor regulating chlorophyll concentration of crop (Rahim et al., 2018) and the using of GA3 has been reported to improve chlorophyll indicators in mung bean crop grown at sandy soils (El Karamany et al., 2019). Foliar application of gibberellic acid greatly stimulates the accumulation of nutrients, such as chlorophyll, in crop and their cellular components. Gibberellic acid stimulates photosynthesis, which in turn increases the production of chlorophyll (Abuzar et al., 2011).

4.12. Antioxidant enzyme (AE)

Result of analysis of variance revealed effect of genotype, different concentration and time of application of gibberellic hormone on Catalase and Peroxidase enzymes was significant at 5% probability level but interaction effect of treatments was not significant (Table 2). Hyola 401 genotype had higher levels of AE (Catalase and Peroxidase enzymes) than other genotypes, which indicates the greater ability of this hybrid against the heat of the end of the season (Table 3). The mean comparison results showed that apply gibberellic hormone increased the concentration of AE compared to the control treatment. So, the maximum amount of catalase (21.65 unit/mg protein) and peroxidase (17.89 unit/mg protein) enzymes was related to use 100 ppm gibberellic hormone and lowest one belonged to control (Table 3). Increasing the activity of AE may be a way for the crop to tolerate environmental stresses (Janda et al., 1999). The effect of gibberellic hormone on increasing the activity of AE has been reported by other researchers in different plants (Bailly, 2004; Ansari et al., 2012). In other words, the use of gibberellic hormone by increasing the activity of AE causes resistance under stress conditions and increases the

effective traits on SY. Factors such as heat stress with the production of oxygen free radicals such as peroxide and hydrogen peroxide cause the destruction of cell membranes, disrupt the germination and crop growth including rapeseed (Ashraf and McNeilly, 2004). Crop can remove oxygen free radicals by antioxidant compounds such as catalase and glutathione reductase enzymes and nonenzymatic compounds such as carotenoids. In fact, by helping to clean the environment of cells from active oxygen, AE are able to reduce the negative effects of environmental stress and help to tolerate stressful conditions (Ashraf and Ali, 2008).

5. Conclusion

Increase of sourcesink balance by the using of crop growth regulators is thus one important facet of investigation. Application Gibberellic (due to use it which growth stage) proved has potential to improve studied traits. According result of current study advised to use Hyola401 hybrid with 100 ppm gibberellic hormone at VPBF growth stage to achieve maximum crop production by farmers.

Acknowledgment

The authors thank all colleagues and other participants, who took part in the study.

Authors Contribution

Somayeh Ghalandari; Study concept and design, acquisition of data, analysis, and interpretation of data, and statistical analysis; Tayeb Sakinezhad; Administrative, technical, and material support, and study supervision; Mani Mojaddam, Shahram Lak and Mojtaba Alavi Fazel: Critical revision of the manuscript for important intellectual content.

Conflict of interests

Authors declared no conflict of interest.

Funding/support

This study did not receive any funding.

References

Abuzar, M. R., Sadozai, G. U., Baloch, M. S., Baloch, A. A., Shah, I. H., Javaid, T. and Hussain, N. 2011. Effect of plant population densities on yield of Maize. *Journal of Animal and Plant Sciences*, 21(4), pp. 692-695.

Agawane, R. B. and Parhe, S. D. 2015. Effect of seed priming on crop growth and grain yield of soybean (*Glycine max* (L) Merill). *The Bioscan*, 10, pp. 265-270.

Alshakhaly, Z. M. and Qrunfleh, M. M. 2018. Effect of plant growth regulators on flower development and quality of five cyclamen persicum hybrids. *In*: Proceedings of the XXX International Horticultural Congress IHC2018: International Symposium on Ornamental Horticulture and XI International, Istanbul, Turkey, 12–16 August, 1263, 215-222.

Akter, A., Ali, E., Islam, M. M. Z., Karim, R. and Razzaque, A. H. M. 2007. Effect of GA3 on growth and yield of Mustard. *International Journal of Sustainable Crop Production*, 2(2), pp. 16-20.

Ansari, O., Choghazardi, H. R., Sharif Zadeh, F. and Nazarli, H. 2012. Grain reserve utilization and seedling growth of treated grains of mountain Rye (*Secale Montanum*) as affected by drought stress. *Cercetări Agronomice in Moldova*, 2(150), pp. 43-48. https://doi.org/10.2478/v10298-012-0013

Ashraf, M. and McNeilly, T., 2004. Salinity tolerance in Brassica oilseeds. *Critical Review of Plant Science*, 23, pp. 157-174. https://doi.org/10.1080/07352680490433286

Ashraf, M. and Ali, Q. 2008. Relative membrane permeability and activities of some antioxidant enzymes as the key determinants of salt tolerance in canola (*Brassica napus* L.). *Environmental and Experimental Botany*, 63(1-3), pp. 266-273. https://doi.org/10.1016/j.envexpbot.2007.11.008

Bailly, C. 2004. Active oxygen species and antioxidants in grain biology. *Grain Science Research*. 14(2), pp. 93-107. DOI:10.1079/SSR2004159

Basuchaudhuri, P. 2016. Influences of plant growth regulators on yield of Soybean. *Indian Journal of Plant Sciences*, 5(4), pp. 25-38. *In*: Solomani, A., Sivakumar, C, Anbumani, S, Suresh, T. and Arumugam, K. 2001. Role of plant growth regulators on rice production: A Review. *Agriculture Review*, 23, pp. 33-40.

Baydar, H. 2000. Effects of gibberellic acid on male sterility, grain yield and oil and fatty acid syntheses of safflower (*Carthamus tinctorius* L.). *Turkish Journal of Biology*, 24, pp. 159-168.

Behera, S., Padhiyari, A. K., Rout, S., Nayak, A., Behera, D. and Nanda, P. K. 2017. Effect of plant growth regulators on morpho-physiological and yield parameters of some sesame (*Sesamum indicum* L.) cultivars. *International Journal of Current Microbiology and Applied Sciences*, 6, pp. 1784-1809. DOI: https://doi.org/10.20546/ijcmas.2017.611.215

Bergmann, B. A., Dole, J. M. and McCall, I. 2016. Gibberellic acid shows promise for promoting flower stem length in four field-grown cut flowers. *Horticulture Technology.* 26, pp. 287-292. DOI:10.21273/HORTTECH.26.3.287

Bibi, M., Hussain, M., Qureshi, M. S. and Kousar, S. 2003. Morpho-chemical and physiological response of sunflower (*Helianthus annuus* L.) to gibberellic acid and nitrogen. *Pakistan Journal of Life and Social Sciences*, 1, pp. 51-53.

Bhatt, K. L. and Singh, A. K. 1997. Effect of different levels of phosphorus, gibberellic acid and picking on grain production of okra (*Abelmoschus esculentus* (L.) Moench). *Vegetable Science*, 24(1), pp. 4-6.

Boultior, C. and Morgan, D. G. 1992. Development of oilseed rape buds, flowers and pods in vitro. *Journal of Experimental Botany*, 43, pp. 1089-1096. https://doi.org/10.1093/jxb/43.8.1089

Bradford, M. 1976. A rapid and sensitive method for the quantitation of protein utilizing the principle of protein-dye binding, *Annual Review Biochemistry*, 72, pp. 248-254. http://dx.doi.org/10.1016/0003-2697(76)90527-3

Bruckner, B. and Blechschmidt, D. 1991. The gibberellic fermentation. *Critical Reviews in Biotechnology*, 11(2), pp. 163-192. DOI: 10.3109/07388559109040621

Buriro, K. A., Soomro, N. S., Siddiqui, M. A., Chang, M. S., Sootaher, J. K., Nangraj, G. M., Siyal, A. L., Wadho, M., Buriro, K. H. and Majeedano, N. A. 2022. Effects of foliar application of Gibberellic Acid3 on the growth and yield of Canola (*Brassica napus* L.) genotypes. *Biological Scientific Review*, 4(1), pp. 1-14. https://doi.org/10.32350/BSR.0401.01

El Karamany, M. F., Sadak, M. S. and Bakry, B. A. 2019. Improving quality and quantity of Mung bean plant via foliar application of plant growth regulators in sandy soil conditions. *Bulletin of the National Research Centre*, 43(61), pp. 1-7. https://doi.org/10.1186/s42269-019-0099-5

Ergin, N. and Kayan, N. 2021. The effects of different gibberellic acid doses and application times on chickpea plants. *Applied Ecology and Environmental Research*, 19(4), pp. 2803-2813. DOI: http://dx.doi.org/10.15666/aeer/1904_28032813

Fadhil, A. H. and Almasoody, M. M. M. 2019. Effect of spraying with gibberellic on growth and yield of three cultivars of Broad bean (*Vicia faba* L.). *Indian Journal of Ecology*, 46(8), pp. 85-89.

Gardner, F. P., Pearce, R. B. and Mitchell, R. L. 1985. Physiology of crop plants. Ames, Iowa State University Press. USA. 121 pp.

George, E. F., Hall, M. A. and De Klerk, G. J. 2008. Plant propagation by tissue culture 3rd Edition, Vol. 1. Springer, Dordrecht, The Netherlands. 501 p.

Ghodrat, V., Rousta, M. J., Tadaion, M. S. and Karampour, A. 2012. Yield and yield components of Corn (*Zea mays* L.) in response to foliar application with indole Butyric acid and Gibberellic. *American-Eurasian Journal of Agricultural and Environmental Sciences*, 12(9), pp. 1246-1251. DOI: 10.5829/idosi.aejaes.2012.12.09.1880

Gouping, C. and Etmal, E. 1993. Efficiency of application of ABT on maize. The 2nd international Training Course on New Type Plant Growth Regulators. Oct. 10-25, 1993. Beijing, China.

Hafeez, U. R., Sajjad, A., Laiq, Z., Zaid, K., Muhammad, A. K., Muhammad, H. and Amin, U. 2018. Yield and growth response of Maize crop to urea and Gibberellic 0038 acid potash salt (Ga-K Salt) in calcareous soil. *Horticulture Arboriculture*, 1(2), 555558. DOI: 10.19080/JOJHA.2018.01.555558

He, J. X. and Li, Q. F. 2013. Mechanism of signaling crosstalk between brassinosteroids and gibberellics. *Plant Signaling Behavior*. 8, 7 e 2486.

Hedden, P. and Sponsel, V. 2015. A century of gibberellic research. *Journal of Plant Growth Regulation,* 34, pp. 740-760. https://doi.org/10.1007/s00344-015-9546-1

Janda, T., Szalai G., Tari, I. and Paldi, E. 1999. Hydroponic treatment with salicylic acid decreases the effects of chilling injury in maize (*Zea mays* L.) plants, *Planta*, 208, pp. 175-180. https://doi.org/10.1007/s004250050547

Khan, M. S. K. 1997. Effect of different levels of nitrogen on growth, yield and quality of wheat. M.Sc. Thesis. Department of Agronomy, Bangladesh Agriculture University. Mymensingh. Bangladesh.

Khan, N. A., Ansari, H. R. and Samiullah, A. 1998. Effect of gibberellic acid spray during ontogeny of mustard on growth, nutrients uptake and yield characteristics. *Journal of Agronomy and Crop Sciences,* 181, pp. 61-63. https://doi.org/10.1111/j.1439-037X.1998.tb00399.x

Leilah, A. A. A. and Khan, N. 2021. Interactive effects of Gibberellic acid and Nitrogen fertilization on the growth, yield, and quality of Sugar Beet. *Agronomy*. 11(137), pp. 1-14. https://doi.org/10.3390/agronomy 11010137

Lovato, A., Dellacecca, V., Montanari, M., Macchia, M. and Magnani, G. 2000. A three years' research of lettuce (*Lactuce sativa* L.). Seed production in two environmental conditions. *Sementi Elette*. 46(6), pp. 19-23.

Mir, M. R., Lone, N. A. and Khan, N. A. 2009. Impact of exogenously applied ethephon on physiological and yield attributes of two mustard cultivars under rainfed conditions. *Applied Biological Research,* 11, pp. 44-46.

Niknejhad, Y. and Pirdashti, H. 2012. Effect of growth stimulators on yield and yield components of Rice (*Oryza sativa* L.) ratoon. *International Research Journal of Applied and Basic Sciences*, 3(7), pp. 1417-1421.

Nizamani, M. R., Ansari, M. A., Siddiqui, M. A., Nizamani, Gh. Sh., Nizamani, F., Naz, M. and Mastoi, A. H. 2018. Effect of gibberellic acid on yield and yield attributes of Canola (*Brasica napus* L.) varieties. *Global Scientific Journal*, 6(8), pp. 865-880.

Pepi, N. S., Surahman, M., Purwoko, S., Tatiek, A. and Suharsi, K. 2014. Effect of GA3 concentration on hybrid rice seed production in Indonesia. *International Journal of Applied Science and Technology*, 4(2), pp. 143-148.

Rahim, H. U., Ahmad, S., Zada, L., Khan, Z., Khan, M. A., Haris, M. and Usman, A. U. 2018. Yield and growth response of maize crop to urea and gibberellic acid potash salt (Ga-K salt) in calcareous soil. *Horticulture Arboriculture*, 1, pp. 35-39.

Ramesh, S., Sudhakar, P., Elankavi, S., Suseendran, K. and Jawahar, S. 2019. Effect of gibberellic acid (GA_3) on growth and yield of Rice (*Oryza sativa* L.). *Plant Archives*. 19(1), pp. 1369-1372.

Riley, J. M. 1987. Gibberellic for fruit set and grain germination. *California Rare Fruit Growers Journal*, 19, pp. 10-12.

Sato, T. 2002. New estimation method for fatty acid composition in oil using near infrared spectroscopy. *Journal of Bioscience Biotechnology and Biochemistry,* 66, pp. 2543-2548. https://doi.org/10.1271/bbb.66.2543

Sarkar, P. K., Haque, M. S. and Karim, M. A. 2002. Effects of GA3 and IAA and their frequency of application on morphology, yield contributing characters and yield of soybean. *Journal of Agronomy*, 1, pp. 119-122. DOI:10.3923/ja.2002.119.122

Singh, B. A., Singh, C. B., Singh, G. P. and Maurya, C. L. 2017. Effect of seed priming on quality parameters of wheat (*Triticum aestivum* L.) grains harvested under irrigated and rainfed conditions. *Journal of Pharmacognosy and Phytochemistry*, 6(4), pp. 1646-1650.

Soliman, A. S. 2019. Plant growth hormones. *Intect Open*. pp. 1-11.

Sosulski, F. W. and Imafidon, G. I. 1990. Amino acid composition and nitrogen-to-protein conversion factors for animal and plant foods. *Journal of Agricultural and Food Chemistry*, 38, pp. 1351-1356. https://doi.org/10.1021/jf00096a011

Taiz, L. and Zeiger, E. 2010. Gibberellics: regulators of plant height. *In*: Zeiger, E. (Ed.), Plant Physiology. Sinauer Associates. Incorporated: Hard Cover. 461-493.

Takahashi, N., Phinney, B. O. and Mac Millan, J. 1991. Gibberellics. Springer- Verlag, New York, USA. http://dx.doi.org/10.1007/978-1-4612-3002-1

Tiwari, D., Pandey, K. P., Giri, S. P. and Dwivedi, J. L. 2011. Effect of GA3 and other plant growth regulators on hybrid rice grain production. *Asian Journal of Plant Sciences*, 10(2), pp. 133-139. DOI: 10.3923/ajps.2011.133.139

Thuc, L. V., Sakagami, J. I., Khuong, N. Q., Orgill, S., Huu, T. N., Lang, N. T. T. and Nhan, P. Ph. 2021. Effects of spraying Gibberellic acid doses on growth, yield and oil content in Black Sesame (*Sesamum indicum* L.). *Asian Journal of Crop Science*, 13, pp. 1-8. DOI: 10.3923/ajcs.2021.1.8

Tsegay, B. A. and Andargie, M. 2018. Grain priming with Gibberellic acid (GA_3) alleviates salinity induced inhibition of germination and seedling growth of *Zea mays* L., *Pisum sativum Var. abyssinicum* A. Braun and *Lathyrus sativus* L. *Journal of Crop Science and Biotechnology*. 21, pp. 261–267. https://doi.org/10.1007/s12892-018-0043-0

Uddin, M. M., Samad, A., Khan, M. R., Begum, S. and Salam, M. A. 1986. Effect of sowing dates on the yield and some of its components of mustard and rapeseed. *Bangladesh Journal of Scientific and Industrial Research*, 21, pp. 160-165.

Ullah, S., Anwar, S., Rehman, M., Khan, S., Zafar, S., Liu, L. and Peng, D. 2017. Interactive effect of gibberellic. acid and NPK fertilizer combinations on ramie yield and bast fiber quality. Scientific Reports, 7, 10647. DOI:10.1038/s41598-017-09584-5

Upadhyay, R. G. and Ranjan, R. 2015. Effect of growth hormones on morphological parameters, yield and quality of soybean (*Glycine max* L.) during changing scenario of climate under mid hill conditions of Uttarakhand. *International Journal of Tropical Agriculture*, 33, pp. 1899-1904.

Uzun, A., Ozcelik, H. and Yilmaz, S. 2012. Evaluation of some selected chickpea (*Cicer arietinum* L.) lines in respect to agronomic and quality traits. *Academic Journal of Agricultural Research,* 1(1), pp. 29-36.

Vekaria, G. B., Rakholiya, K. D., Vora, V. D., Patel, J. T., Sutaria, G. S. and Vekariya, P. D. 2017. Response of

sesame (*Sesamum indicum* L.) to growth regulator under dry farming condition. *International Journal of Current Microbiology and Applied Sciences*, 6, pp. 1113-1120. DOI: 10.20546/ijcmas.2017.603.129

Wang, X., Sun, L., Li, W., Peng, M., Chen, F., Zhang, W., Sun, C., Chen, S., Hua, W. and Zhang, J. 2020. Dissecting the genetic mechanisms of waterlogging tolerance in Brassica napus through linkage mapping and a genome-wide association study. *Industrial Crops and Products*. 1(147), 112269. https://doi.org/10.1016/j.indcrop.2020.112269

Zang,Y. X., Chun, I. J., Zhang, L. L., Hong, S. B., Zhen, W. W. and Xu, K. 2016. Effect of gibberellic acid application on plant growth attributes, return bloom, and fruit quality of rabbit eye blueberry. *Journal of Science and Horticulture*, 200, pp. 13-18. DOI: 10.1016/j.scienta.2015.12.057