Available online freely at www.isisn.org

Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2020 17(2): 1069-1081. **OPEN ACCESS**

Relationship among growth, yield and nutritional contents in maize (*Zea mays* L.) on GA_3 applications

Maryam Farooq[1], Khalid Hussain[1*], Khalid Nawaz[1], Arifa Nazeer[1], Syed Saqib Ali[1], Zobia Bashir[1], Muniza Sarfraz[1], Noshia Arshad[1] and Anam Younas[1] and Javaria Tariq[1]

Department of Botany, University of Gujrat, Gujrat, **Pakistan**

***Correspondence:** khalid.hussain@uog.edu.pk **Received 14-05-2020, Revised: 06-06-2020, Accepted: 08-06-2020 e-Published: 09-06-2020**

Many researcher evaluated the effect of gibberellic acid (GA_3) on maize for its growth and yield but there is no or less information about the performance of nutritional components and its relationship. To evaluate the impact of GA_3 on growth, yield, nutritional components and its relationship, experiments were conducted on two varieties (Pahari Makai and Desi Makai) during 2018-19. Different levels of GA_3 (0, 25, 50 and 75 mmol L^{-1}) were applied after the 14 days of the seed germination as foliar application. It was noted that the application of GA_3 increased the root development, vegetation and foliage growth at seedling and vegetative stages in maize varieties. Relative growth rate (RGR), net assimilation rate (NAR) and photosynthetic pigments were also increased. Catalase (CAT) activities were increased and peroxidase dismutase (POD) activities were reduced at seedling stage. Seed yield was significantly increased by foliar spray of GA_3. Nutritional components i.e. dietary fibers, total protein, and carbohydrates, concentration of potassium (K) and phosphorus (P) were also significantly increased with the applications of GA_3. All the levels of GA_3 enhanced the growth, yield and nutritional components in maize but 50 mmol L^{-1} concentration was superior to enhance all these attributes. It was noted that variety Pahari Makai was better for growth, yield and photosynthetic pigments while Desi Makai had higher nutritional values i.e. 2.69 dietary fibers, 3.54 protein contents, 27.8 carbohydrate contents, 0.035 contents of K and 8.1 contents of P based upon g per 100 gram seeds with the applications of 50 mmol L^{-1} GA_3. Pearson correlation showed that all nutritional contents and seed yield had positive correlations and directly involved with each other enhance the yield and nutritional value of maize. It was concluded that 50 mmol L^{-1} applications of GA_3 were useful to enhance growth and yield and nutritional values of maize with positive relationship.

Keywords: Maize, GA_3, Growth, Yield, Antioxidant activities, Quality

INTRODUCTION

Maize (*Zea mays* L.) ranked 3rd position all around world after wheat and rice (Sandhu et al., 2007). It is expected that by the year 2020 that maize will become the top leading crop of the globe (Jones, 2009). Throughout the world, maize is used for various purposes that include the various food products for human, production of cattle feed and biofuel (Carena et al., 2010). The grains comprise different constituents with different proportions such as 5.8% fiber, 72% starch, 3% sugar, 10% protein, 4.8% oil and 1.7% ash (Hussain et al., 2007).

Plant growth regulators (PGRs) are chemical substances that control the plant growth as well as its development. If the plant lacks these chemical substances, formerly plant will turn into a group of indistinguishable cells (Gomez-Roldan et al., 2008). PGRs change the plant physiology when they are used in small quantity and then ultimately change the quality and yield of plant (Sajid et al., 2016). Among PGRs, gibberellic acid (GA_3) plays important role in various developmental and biochemical processes of plants (Crozier, 2000). In plants, gibberellic acid is naturally produced, however if it is applied as the foliar application and then they trigger the division of cell, enhance the production and it also allows plant to acclimatize various other situations of the environment (Chauhan et al., 2009). Gibberellins also regulate the seed germination, growth of the reproductive organs and cell division (Colebrook et al., 2014). Gibberellic acid produces disruption in different process such as elongation and cell division (Roy et al., 2010).

When gibberellic acid is applied on the plants, it may cause the biochemical effects on growth of plant and furthermore influences the photosynthetic processes. GA_3 also stimulates various activities in the plant cells. Plant length is increases; leave size and the elongation of roots are all the improved plant productivity (Kondhare et al., 2014). GA_3 produce numerous effects on various plant processes that are associated with the development such as seed germination, fruit setting and leaf expansion (Davies, 1995). GA_3 also stabilizes the microtubules in different plant organs (Janda et al., 2012). GA_3 also enhances the yield of a plant (Rohamare et al., 2013).

Many researcher evaluated the impact of GA_3 on maize but so far, its effects on nutritional contents and its relationship have not been studied. For this purpose, this study was carried out to find the relationship of nutritional values of maize with GA_3.

MATERIALS AND METHODS

Experiment was conducted at University of Gujrat, Gujrat**,** Pakistan, during 2018-19. Seeds of two maize varieties (Desi Makai and Pahari Makai) were obtained from Punjab Agriculture Department, Gujranwala, Pakistan. The sandy loam soil was prepared by taking of approximately 60 percent sand, 10 percent clay and 30 percent silt particles. The soil was mixed with organic manure with 1:1 ratio; no synthetic fertilizer was used and no disease was observed during the experiment. Seeds were planted in plastic pots of having 30 cm length containing 8 kg of clayey soil. Four levels of treatment of GA_3 (0, 25, 50, 75 mmol L^{-1}) was applied as a foliar application after 14 days germination. Irrigation was applied with the interval of a week.

The experiment was arranged in a completely randomized design with 3 replicates. Data related to morphological and physiological attributes and antioxidant activities was collected at seedling and vegetative stages i.e. root and shoot lengths, root and shoot dry weights, leaf area, photosynthetic pigments and antioxidants activities of catalase and peroxidase. While, the data of relative growth rate (RGR), net assimilation rate (NAR), nutritional values and yield attributes were recorded at maturity.

RGR was calculated as:

$$RGR = \frac{1}{W} \times \frac{\Delta W}{\Delta T}$$

Where, W= Dry shoot weight at initial stage; ΔW =Dry shoot weight at final stage – Dry shoot weight at initial stage; ΔT =Number of days between initial and final stage.

Net assimilation rate (NAR) was determined by the formula:

$$NAR = \frac{W2-W1}{T2-T1} \times \frac{\log L2-\log L1}{L2-L1}$$

Where, W1= Shoot dry weight at initial stage; W2=Shoot dry weight at final stage; L1=Leaf area at initial stage; L2=Leaf area at final stage; T1=Number of days for initial stage; T2=Number of days for final stage.

Leaf area was determined with a portable handheld leaf area meter (CI-203 Laser Scanner, Bio-Science, Camas, Washington, USA). Chlorophyll a, b, and total, and carotenoids, were estimated using the method of Arnon (1949). Total carbohydrates were estimated with the Anthrone method. Soluble protein was estimated following Bradford (1976). Catalase and peroxidase activities were determined using the method of Chance and Maehly (1955). Potassium (K^+) contents were determined with a flame photometer (model PFP7, Jenway Staffordshire, UK). Phosphorus (P) content was determined with a spectrophotometer following the procedure described by Hernández et al. (2005).

Data were subjected to analysis of variance in Minitab (Version: 19.2.0, Coventry, UK). Mean values were compared with Tukey's Test.

RESULTS

There were following results of maize obtained by the treatment of Gibberellic Acid (GA_3) on maize.

Root development in maize:

There were highly significant ($P \leq 0.001$) effect of different levels of GA_3 for the enhancement of root developing attributes (Table 1).

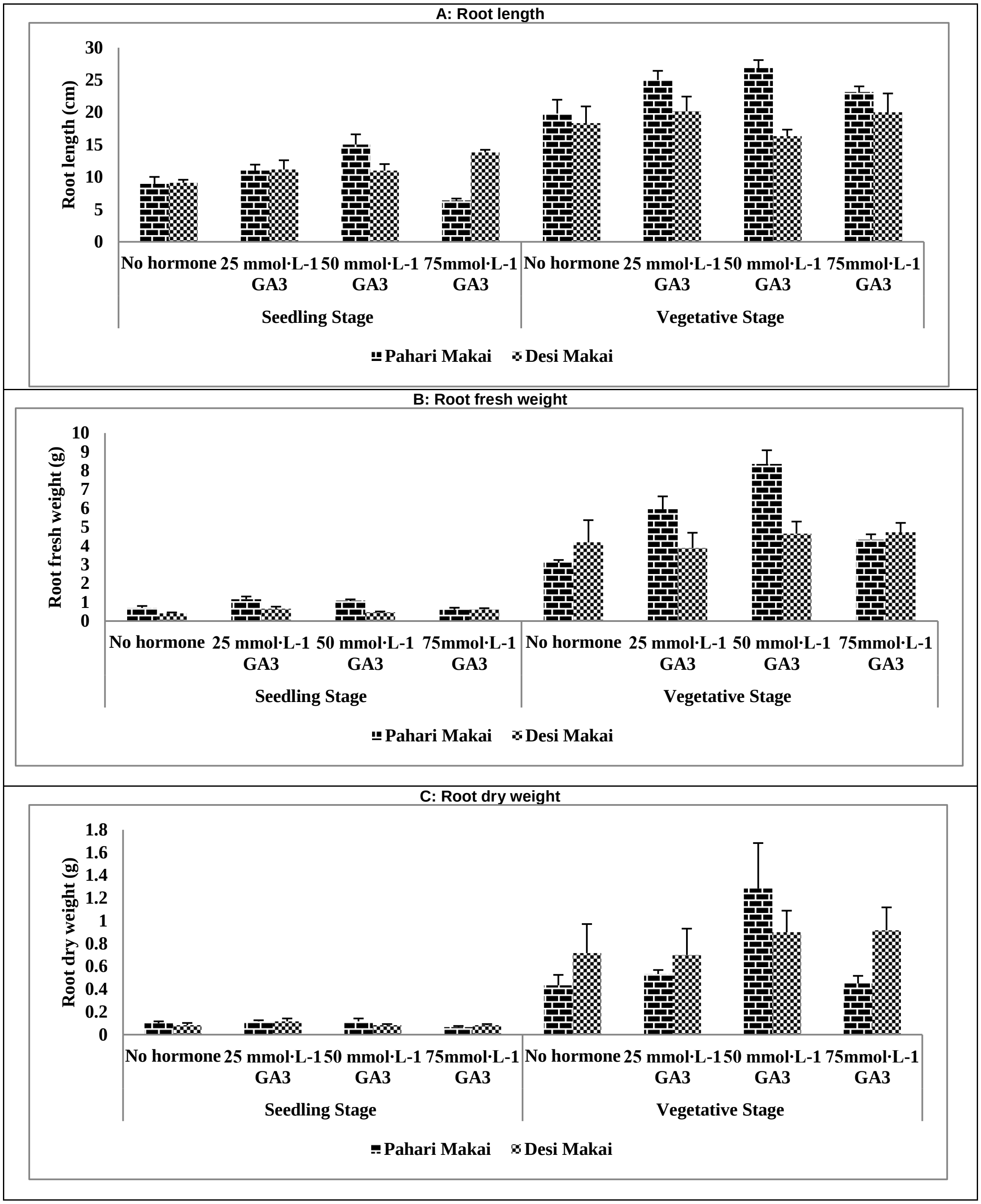

Figure 1: Development of root in Maize due to the effect of GA_3

Table 1: Means squares (MS) from the Analysis of Variance (ANOVA) for root development of Maize under the effect of GA_3

Source of Variance	df	Root length		Root fresh weight		Root dry weight	
		Seedling stage	Vegetative stage	Seedling stage	Vegetative stage	Seedling stage	Vegetative stage
Main effects GA_3	3	17.162**	13.467**	0.153**	8.568***	0.001**	0.338*
Variety	1	5.320ns	149.500**	0.735**	6.933*	0.001**	0.338*
Interaction GA_3×Variety	3	34.021*	22.950*	0.118*	7.329*	4.166*	0.106**
Error	16	9.079	33.942	0.0767	4.308	6.944*	0.200*
Total	23						

*,**, *** = significant at P≤ 0.05, 0.01, or 0.001, respectively

Root length was increased at seedling and vegetative stage of maize except for variety Pharai Makai at seedling stage with the applications of 75mmol·L^{-1} of GA_3 (Figure 1A). There were significant interactions among GA_3 and variety. Maximum root length was found at 50mmol·L^{-1} of GA_3 at seedlings and vegetative stages in variety Pharai Makai (Figure 1A). Root fresh and dry weights have also significantly increased with the applications of GA_3. There were significant results for interaction among varieties and its interaction with GA_3 (Table 1). At seedling stage, higher root fresh weight was noted in Pharai Makai with the applications of 25mmol L^{-1} of GA_3. There was higher root fresh weight in Pharai Makai with 50mmol·L^{-1} of GA_3 application at vegetative stage (Figure 1B). Similarly, root dry weight also increased significantly with the application of GA_3 at seedling and vegetative stages (Table 1). At seedling stage, higher root dry weight was noted in Pharai Makai at both the growth stages of maize. Higher root dry weight was noted in Pharai Makai with 25, 50mmol·L^{-1} of GA_3 applications at seedling and vegetative stages, respectively (Figure 1C).

Vegetation and foliage development of maize:

Effect of GA_3 applications was significant effect for the development of vegetative and foliage growth of maize i.e. shoot lengths, shoot fresh and dry weights. There was a significant effects to increase the shoot length at seedling stage while it was highly significant results at vegetative stage (Table 2). Interactions for GA_3 with variety were significant. Higher shoot length was noted in variety Pahari Makai with 50mmol L^{-1} of GA_3 during seedlings as well as at vegetative stage (Figure 2A). Shoot fresh and dry weights were also significantly increased with the applications of different levels of GA_3 (Table 2). Higher shoot fresh and dry weights were noted in variety Pahari Makai both for seedlings and vegetative stages (Figure 2B-C). GA_3 significantly increased the leaf area of maize. Higher leaf area was calculated in Pahari Makai at both the growth stages with 50 mmol L^{-1} of GA_3 (Figure 2D). Overall, 50mmol L^{-1} of GA_3 was more effective to enhance the vegetation and foliage attributes of maize in Pahari Makai.

Photosynthetic pigments and physiological activities:

Effect of different levels of GA_3 was highly significant on photosynthetic pigments i.e. chl. a, b, total chlorophyll and carotenoids in maize at seedling stage while, it was significant at vegetative stage (Table 3). Photosynthetic pigments were increased with the applications of GA_3. Maximum increase in Chl. a, b and total chl was noted at seedlings stage in variety Pahari Makai with the applications of 50 mmol L^{-1} of GA_3 except for chl b that was high in Desi Makai (figure 3A-C). In case of carotenoids, variety Desi Makai responded well to enhance its concentration at seedlings and Pahari Makai showed higher carotenoid contents at vegetative stages (Figure 3D).

Data related to relative growth rate (RGR) and net assimilation rate (NAR) is presented in Table 3. There was a highly significant effect of GA_3 for RGR and NAR while effect between varieties was no-significant. Interactions between GA3 and variety was significant for RGR and NAR. Maximum RGR was noted at 75mmol L^{-1} of GA_3 in both maize varieties (Figure 4A).

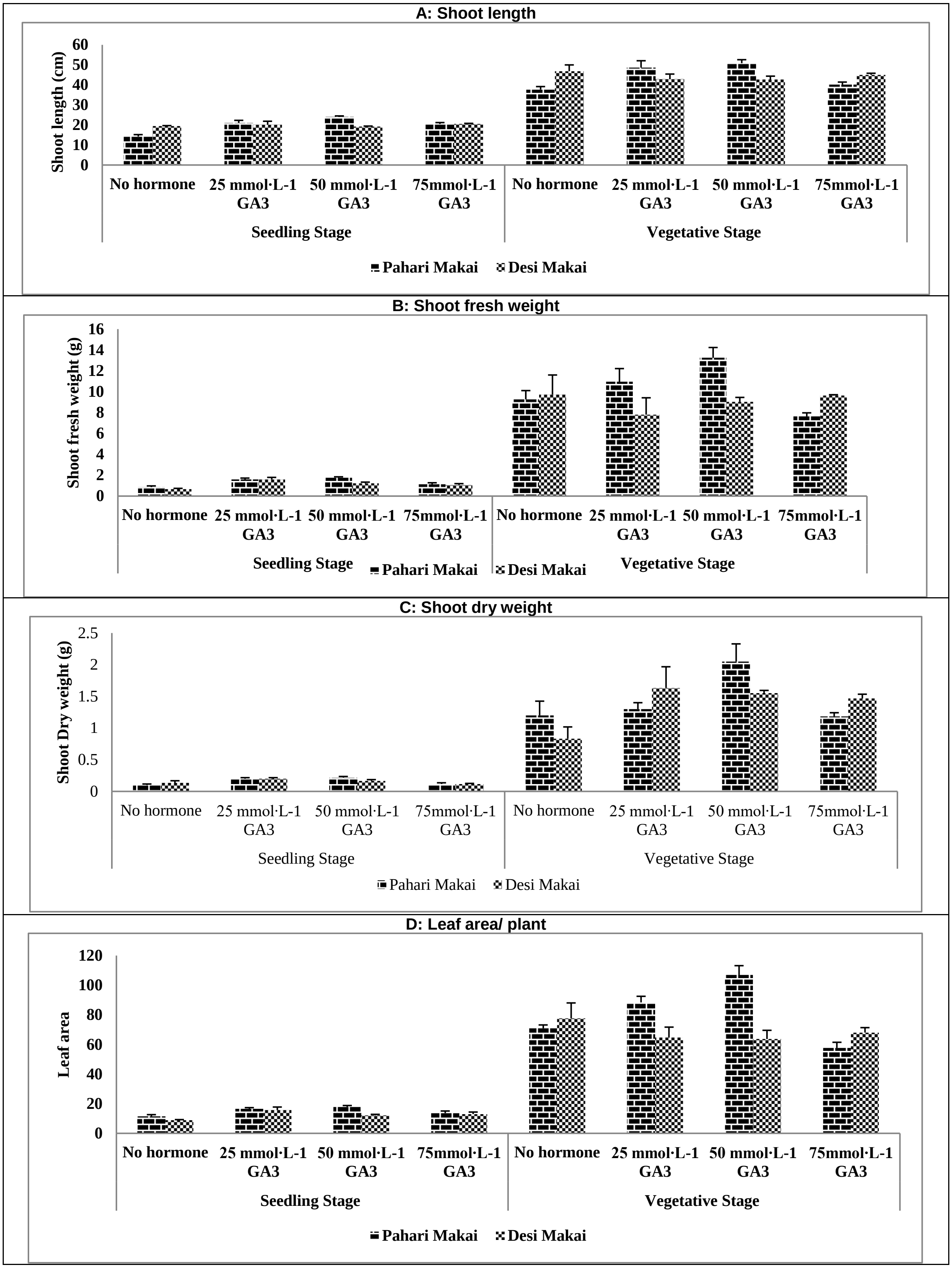

Figure 2: Shoot and leaf development of root in Maize due to the effect of GA_3

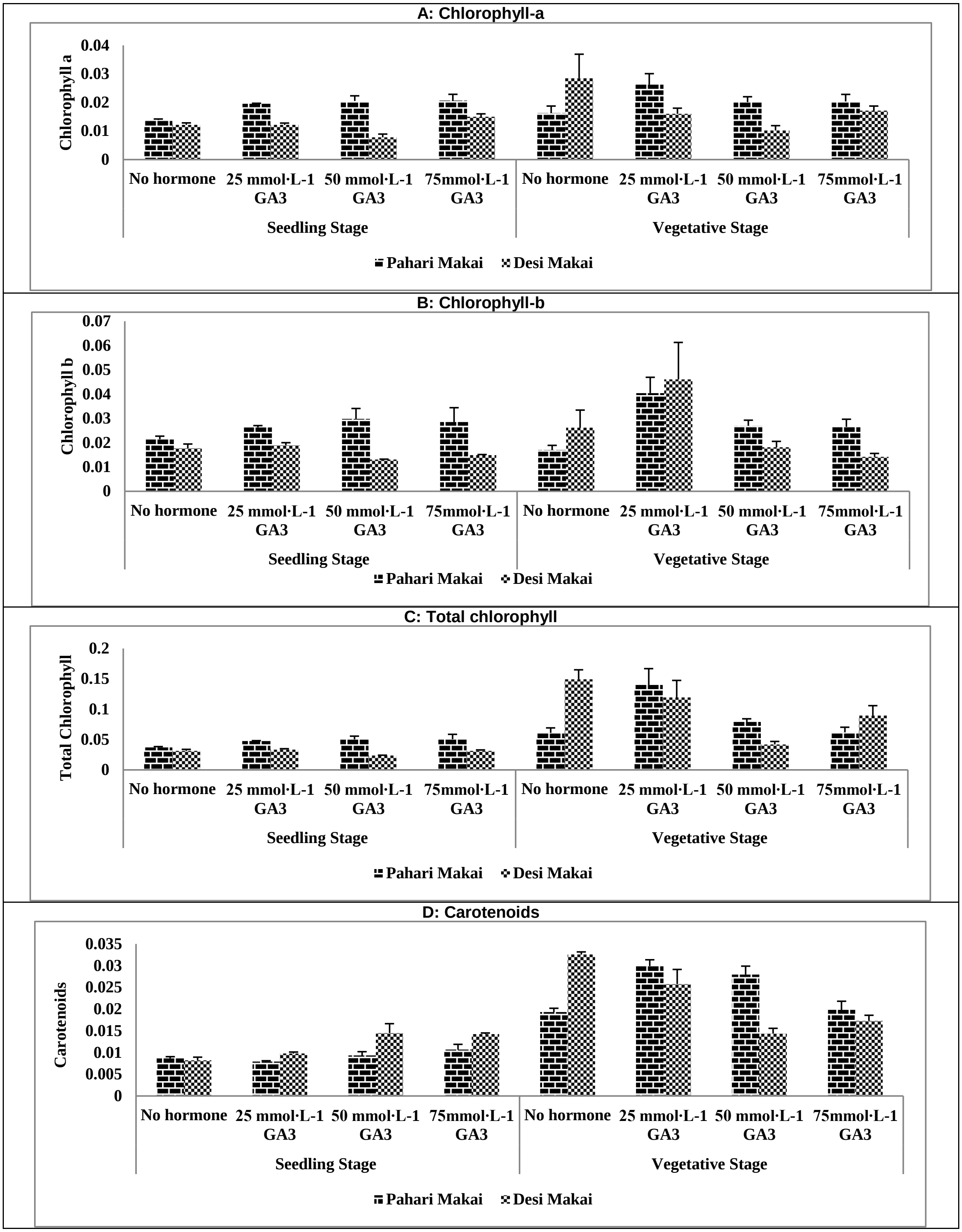

Figure 3: Photosynthetic pigments in Maize due to the effect of GA_3

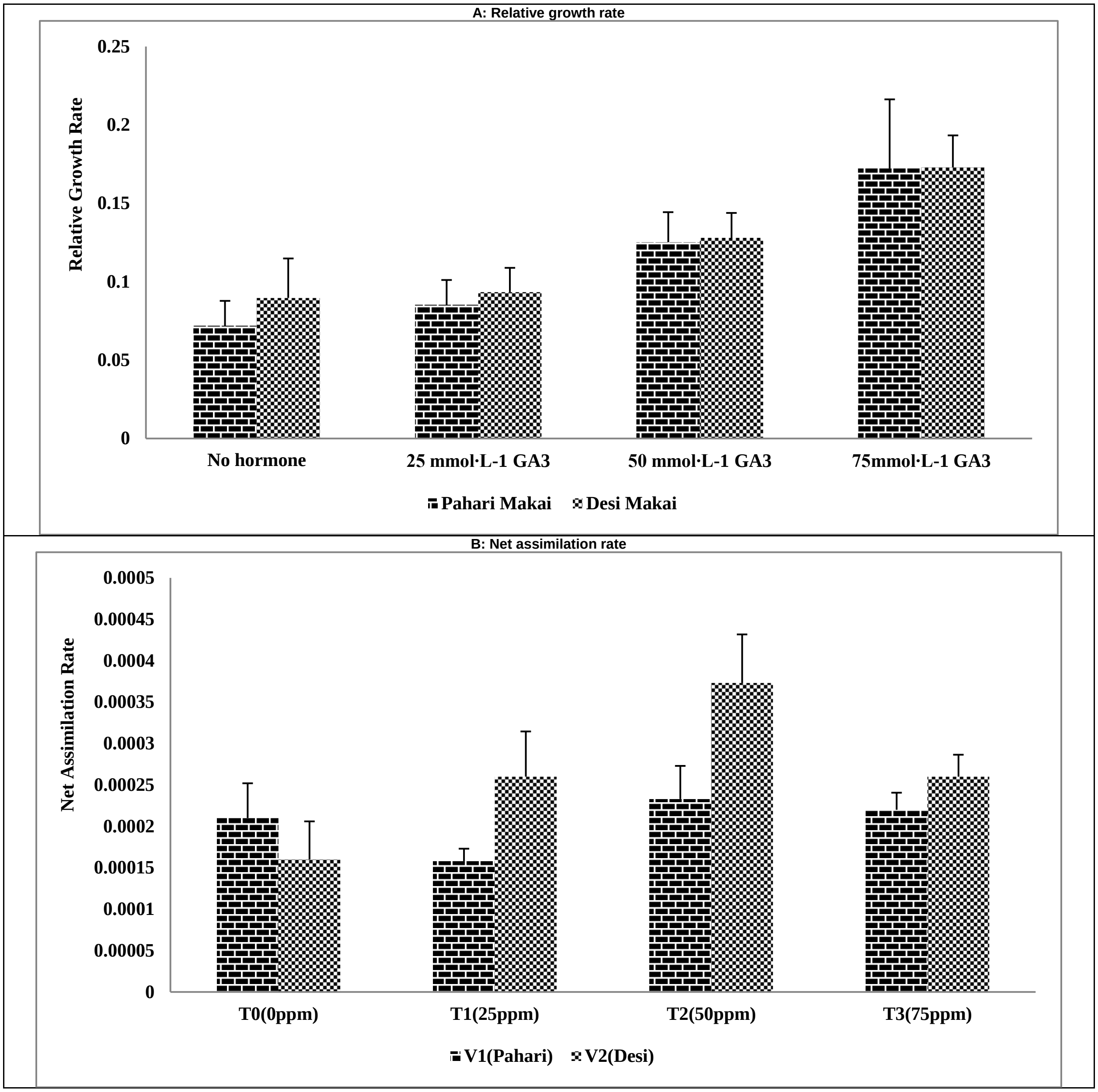

Figure 4: Photosynthetic pigments in Maize due to the effect of GA_3

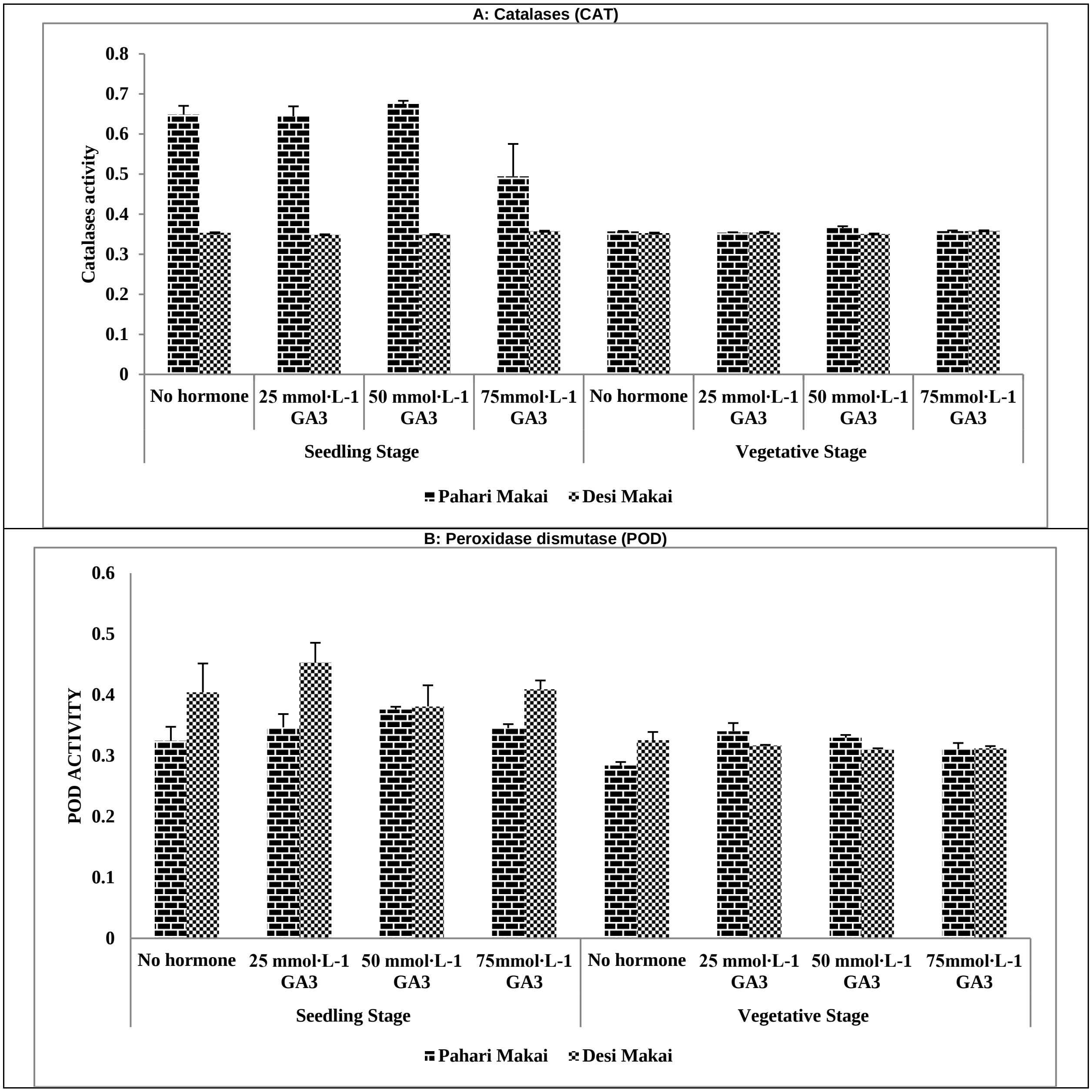

Figure 5: Antioxidant activities of Maize due to the effect of GA_3

Table 2: Means squares (MS) from the Analysis of Variance (ANOVA) for shoot and leaf growth of Maize under the effect of GA_3

Source of Variance	df	Shoot length		Shoot fresh weight		Shoot dry weight		Leaf area/plant	
		Seedling stage	Vegetative stage	Seedling stage	Vegetative stage	Seedling stage	Vegetative stage	Seedling stage	Vegetative stage
Main effects GA_3	3	26.267*	30.548**	0.8612**	6.712**	0.012*	0.633**	35.953*	511.000*
Variety	1	0.081ns	0.008*	0.24*	9.003ns	0.012*	0.633**	73.605*	932.631*
Interaction GA_3×Variety	3	25.958*	103.788*	0.0936**	12.959*	1.041*	0.023**	28.657*	981.696*
Error	16	6.995	43.179	0.1476	10.892	0.001*	0.289*	16.063	315.523
Total	23								

*,** = significant at P≤ 0.05, 0.01, respectively.

Table 3: Means squares (MS) from the Analysis of Variance (ANOVA) for photosynthetic pigments and physiological activities of Maize under the effect of GA_3

Source of Variance	df	Chlorophyll-a		Chlorophyll-b		Total chlorophyll		Carotenoids		Relative growth rate (RGR)	Net Assimilation rate (NAR)
		Seedling stage	Vegetative stage	Seedling stage	Vegetative stage	Seedling stage	Vegetative stage	Seedling stage	Vegetative stage	Vegetative stage	Vegetative stage
Main effects GA_3	3	2.624*	6.081**	9.883**	7.158*	6.330**	0.005*	2.578**	1.088*	0.0104**	1.642***
Variety	1	2.830***	4.728ns	6.419**	1.560*	0.001**	0.001**	3.899*	1.814*	3.2398ns	2.049ns
Interaction GA_3×Variety	3	3.160*	1.648**	5.211*	1.686**	1.164ns	0.004**	8.697ns	1.853**	8.6415*	1.033*
Error	16	1.289	1.244	6.707	3.971	1.183	0.002	8.780	2.858	0.0049	1.503
Total	23										

*,**, *** = significant at P≤ 0.05, 0.01, or 0.001, respectively.

Table 4: Means squares (MS) from the Analysis of Variance (ANOVA) for antioxidant activities of Maize under the effect of GA_3

Source of variance	df	Catalase activity		Peroxidase activity	
		Seedling stage	Vegetative stage	Seedling stage	Vegetative stage
Main effects GA_3	3	0.009*	2.266ns	0.001*	6.391ns
Variety	1	0.417*	1.215*	0.024*	4.166*
Interaction GA_3×Variety	3	0.010ns	8.194**	0.002*	0.001*
Error	16	0.008	4.825	0.006	6.082
Total	23				

ns= non-significant; * significant at P≤ 0.05

Table 5: Means squares (MS) from the Analysis of Variance (ANOVA) for total yield and quality attributes of Maize under the effect of GA_3

Source of variance	df	Yield per plant	Dietary fibers	Total protein	Total carbohydrate	K contents	P contents
Main effects GA_3	3	3.324***	2.432***	0.0547**	0.0047***	0.0075***	0.0053**
Variety	1	3.784*	1.421*	0.0345*	0.0144ns	0.0098*	0.0042*
Interaction GA_3×Variety	3	0.348***	0.674**	0.00843*	0.0063*	0.0034*	0.0063*
Error	16	0.018	0.367	0.0054	0.0112	0.0045	0.0034
Total	23						

*,**, *** = significant at P≤ 0.05, 0.01, or 0.001, respectively.

Table 6: Mean comparison from Tukey's test for yield and nutritional components of maize due to GA_3

Treatments	Yield per plant (g)		Dietary fiber (g/100gram)		Protein (g/100gram)		Carbohydrate (g/100gram)		K (g/100gram)		P (g/100gram)	
	Pahari Makai	Desi Makai	Pahari Makai	Desi Makai	Pahari Makai	Desi Makai	Pahari Makai	Desi Makai	Pahari Makai	Desi Makai	Pahari Makai	Desi Makai
Control	2.14±0.1 C	2.07±0.02 D	1.94±0.01 D	1.81±0.04 C	3.04±0.01 C	2.94±0.03 D	18.4±0.03 C	22.4±0.06 B	0.027±0.01 C	0.021±0.01 D	7.6±0.04 C	7.2±0.02 C
25 mmol L^{-1} GA_3	2.79±0.02 B	2.43±0.02 C	2.34±0.02 C	2.11±0.03 B	3.33±0.01 B	3.04±0.02 C	21.6±0.02 B	26.6±0.09 A	0.032±0.01 A	0.026±0.02 C	8.6±0.04 B	7.7±0.04 B
50 mmol L^{-1} GA_3	3.11±0.01 A	2.76±0.03 B	2.69±0.02 A	2.36±0.03 A	3.47±0.04 A	3.54±0.01 A	26.5±0.05 A	27.8±0.08 A	0.033±0.02 A	0.035±0.01 A	9.4±0.06 A	8.1±0.03 A
75 mmol L^{-1} GA_3	3.07±0.01 A	2.95±0.01 A	2.55±0.01 B	2.41±0.04 A	3.27±0.03 B	3.44±0.04 B	22.4±0.02 B	26.5±0.11 A	0.031±0.01 A	0.031±0.01 B	9.3±0.02 A	7.9±0.03 A

Different alphabet letter show the significant variations

Table 7: Pearson correlation of maize due to GA_3 applications

	Gibberellic acid	Total seed yield	Dietary fibres	Protein contents	Carbohydrates	K contents
Total seed yield	0.850339299					
Dietary fibres	0.965016831	0.933592844				
Protein contents	0.813390051	0.969687033	0.861767361			
Carbohydrates	0.850701068	0.99859316	0.925277798	0.981147621		
K contents	0.873333765	0.953305204	0.887001814	0.989431387	0.967009036	
P contents	0.688309881	0.966948639	0.817625927	0.946829515	0.965658763	0.895793

r value >0 indicates positive correlation.

While higher NAR was present in variety Desi Makai at 50 mmol L^{-1} of GA_3.

Antioxidant attributes:

Mean squares in ANOVA Table 4 showed that antioxidant activities i.e. catalase (CAT) and peroxidase dismutase (POD) significant effect in response to GA3 at seedling stage while, it was non-significant at vegetative stage. CAT activities were reduced while POD were increased at seedling stage (Figure 5). Maximum reduction in CAT was observed in Desi Makai at 50 mmol L^{-1} of GA_3 (Figure 5A). Maximum increase in POD was observed in Desi Makai at 25 mmol L^{-1} of GA_3 at seedling stage (Figure 5B).

Yield attributes:

Data regarding the yield parameters is given in Table 5. It was noted that seed yield attributes showed highly significant results to GA_3. Mean comparison showed that higher seed yield was present in Desi Makai at 50 mmol L^{-1} of GA_3 (Table 6). All the levels of GA_3 helped to increase the seed yield significantly as compared to control.

Nutritional contents:

Various important nutritional components i.e. dietary fibers, total protein, and carbohydrates, concentration of potassium (K) and phosphorus (P) of maize varieties were studied to find the influence of different levels of GA_3. There was a highly significant effects of GA_3 for all nutritional components (Table 5). Higher nutritional values were noted in variety Desi Makai at 50 mmol L^{-1} of GA_3 (Table 6). There were 2.69 dietary fibers, 3.54 protein contents, 27.8 carbohydrate contents, 0.035 contents of K and 8.1 contents of P based upon g per 100 gram seeds.

Pearson correlations:

Correlations among all the nutritional contents and seed yield is presented in Table 7. From correlation it was noted that all nutritional contents and seed yield had positive correlation with each other under GA_3 applications. All these variables had direct relationship with each other enhance the seed yield as well as nutritional values.

DISCUSSION

Results indicated the root and shoot development and foliage growth was increased with the applications of GA_3. Gibberellins regulate the cell division due to that growth of the organs increase (Colebrook et al., 2014). Gibberellins change the plant physiology when they are used in small quantity and then ultimately change the quality and yield of plant (Sajid et al., 2016). Gibberellic acid produces disruption in different process such as elongation and cell division (Roy et al., 2010). GA_3 plays important role in seed germination and plant growth by the regulation of signaling pathway (Cavusoglu and Sulusogly, 2015).

Hamayun et al. (2010) noted an increase the plant fresh weight (g) through the treatment of GA_3 in soybean plant. The increase root fresh weight of maize is consistent with the findings of Jasmine and John (2012) also observed that the fresh weight is increased with treatment of gibberellic acid in root of okra plant. The increased root dry weight of maize is consistent with results of Rohamare et al. (2013) displayed that the foliar application of gibberellic acid with the concentration of 50ppm improved the dry biomass of ajwain in comparison to control. Paroussi et al. (2002) observed that the gibberellic acid increased total leaf area (cm^2) of maize.

As results revealed an increase in chlorophyll contents by GA_3 at different level. The increased content of chlorophyll a with GA_3 is agreement with Salehi Sardoei et al., (2014) observed an increased the chlorophyll contents in Ficus benjamina with treatment of gibberellic acid up to 250 milligram per liter. Janowska and Andrzejak (2010) the plants that are treated with GA_3 have maximum chlorophyll concentration in their leaves. Dijkstra et al., (1990) stated that an increase in RGR of Glycine max plant with GA_3 treatment. The increased net assimilation rate of maize by GA_3 is similar to the findings of Sarkar et al., (2002) found an enhancement in NAR with gibberellic acid. An increased net assimilation rate (NAR) with gibberellic acid is the main reason for the promotion of early growth of the Rice plant by the GA_3 treatment (Katayama and Akita, 1989).

The increased activity of POD by the treatment of gibberellic acid is in agreement with the Sharaf-Eldin et al., (2007) who revealed the gibberellic acid (GA_3 enhanced the phenolic substances which are successively linked with the increased activity of antioxidants. Increase in seed yield and nutritional values of maize by GA_3 which is in accordance with previous findings of Xu and Li (1988) found that in rice, GA_3 produced the 13 percent greater yield of seeds. As it was found that applications of GA_3 improved the maize nutritional value. Similarly, Singh et al., (2011) found that GA_3 application improved the nutritional contents of broccoli. Chanwala et al., (2019) found that GA_3 applications increased nutritional components as ascorbic acid in broccoli. Sawant et al. (2010) reported the better quality of cabbaged food obtained by the application GA_3 with high nutritional contents. Khamparia and Tiwari (2002) noted that GA_3 applications enhanced the nutritional values in the bulbs of onion.

CONCLUSION

It was concluded that 50 mmol L^{-1} applications of GA3 were useful to enhance growth and yield and nutritional values of maize with positive relationship.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

ACKNOWLEGEMENT

Authors would like to pay acknowledgement whole faculty and staff, Department of Botany, University of Gujrat for their support and help.

AUTHOR CONTRIBUTIONS

For this paper, MF has conducted the field and lab experiments. KH and KN supervised the research. AN, SSA and ZB helped in data collection and draft writing. MS, NS, AY and JT conducted statistical analysis, graphs and facilitated for literature collection.

REFERENCES

Arnon DI, 1949. Copper enzymes in isolated chloroplasts. Polyphenol oxidase in *Beta vulgaris*. Plant Physiol. 24: 1-15.

Carena, MJ, Hallauer AR, Filho JBM, 2010. Quantitative genetics in Maize breeding. Springer New York.

Cavusoglu A, Sulusoglu M, 2015, Effects of gibberellic acid (GA_3), indole-3-acetic acid (IAA) and water treatments on seed germination of *Melia azedarach* L. Scientific Papers. Series B, Horticulture, 59:319-326.

Chance B, Maehly AC,1955. Assay of Catalase and Peroxidase. Methods in Enzy. 2: 764-775.

Chanwala P, Soni AK, Deepika S, Choudhary G, 2019. Effect of Foliar Spray of Plant Growth Regulators on Growth and Quality of Sprouting Broccoli (Brassica oleraceavar. italicaL.). Int. J. Curr. Microbiol. App. Sci. 8 (08): 1846-1852.

Chauhan JS, Tomar YK, Singh IN, Ali S, Debarati A, 2009. Effect of growth hormones on seed germination and seedling growth of black gram and horse gram. J. Am. Sci. 5(5): 79-84.

Colebrook EH, Thomas SG, Phillips AL, Hedden P, 2014. The role of gibberellin signalling in plant responses to abiotic stress. J. Exp. Biol. 217(1): 67-75.

Crozier A 2000 Biosynthesis of hormones and elicitor molecules. In: Buchanan BB, Gruissem W, Jones RL (eds) Biochemistry and molecular biology of plants. American Society of Plant Physiology, Rockville, pp 850-929.

Davies PJ, 1995. The plant hormones: their nature, occurrence, and functions. In: Davies, P.T. (ed.), Plant hormones, 1-12. Kluwer Academic Publishers, Dordrecht.

Dijkstra P, Reegen HT, Kuiper PJ, 1990. Relation between relative growth rate, endogenous gibberellins, and the response to applied gibberellic acid for *Plantago major*. Physiol. Plantarum. 79(4): 629-634.

Gomez-Roldan V, Fermas S, Brewer PB, et al., 2008. Strigolactone inhibition of shoot branching. Nature 455(7210): 189-194.

Hamayun M, Khan SA, Khan AL, et al., 2010. Exogenous gibberellic acid reprograms soybean to higher growth and salt stress tolerance. J. Agri. Food Chem. 58(12): 7226-7232.

Hussain N, Khan AZ, Akbar H, Bangash NG, Khan Z, Idrees M, 2007. Response of maize varieties to phosphorus and potassium levels. Sarhad J. Agri. 23(4): 881-888.

Janda K, Hideg E, Szalai G, Kovacs L, Janda T, 2012. Salicylic acid may indirectly influence the photosynthetic electron transport. J .Plant Physiol.169(10): 971-978.

Janowska B, Andrzejak R, 2010. Effect of gibberellic acid spraying and soaking of rhizomes on the growth and flowering of calla lily (*Zantedeschia spreng*.). Acta Agrobot. 63(2): 155-160.

Jasmine MS, John MA, 2012. Effects of gibberellic acid on seedling growth, chlorophyll content and carbohydrate metabolism in okra (*Abelmoschus esculentus* L. Moench) genotypes under saline stress. J. Chem. Sci. 2(7): 72-74.

Jones TJ, 2009. Maize tissue culture and transformation: the first 20 years. In: *Molecular Genetic Approaches to Maize improvement,* eds A. L. Kriz and B. A. Larkins (Heidelberg: Springer), 7-27.

Katayama K, Akita S, 1989. Effect of exogenously applied gibberellic acid (GA_3) on initial growth of rice cultivars. Japan J. Crop. Sci. 58(2): 217-224.

Khamparia SK Tiwari K 2006 Effect of growth regulators on yield, nutritional and storage qualities of onion bulb. Ann. Plant Soil Res. 9 (1): 33-35.

Kondhare KR, Hedden PS, Kettlewell PS, Farrell AD, Monaghan JM, 2014. Use of the hormone-biosynthesis inhibitors fluridone and paclobutrazol to determine the effects of altered abscisic acid and gibberellin levels on pre-maturity α-amylase formation in wheat grains. J. Cereal Sci. 60(1): 210-216.

Paroussi G, Voyiatzis DG, Paroussis E, Drogoudi PD, 2002. Growth, flowering and yield responses to GA_3 of strawberry grown under different environmental conditions. Sc.i Horti. 96(1-4): 103-113.

Rohamare Y, Nikam TD, Dhumal KN, 2013. Effect of foliar application of plant growth regulators on growth, yield and essential oil components of ajwain (*Trachyspermum ammi* L.). Int J Seed Spices 3(2): 34-41.

Roy R, Rahim MA, Alam MS 2010 Effect of starter solution and GA_3 on growth and yield of cabbage. J. Agrofor. Environ. 3(2): 187-192.

Sajid M, Amin N, Ahmad H, Khan K, 2016. Effect of gibberellic acid on enhancing flowering time in *Chrysanthemum morifolium*. Pak. J. Bot. 48(2): 477-483.

Sandhu KS, Singh N, Malhi NS, 2007. Some properties of corn grains and their flours I: Physicochemical, functional and chapati-making properties of flours. Food Chem. 101(3): 938-946.

Sardoei AS, Rahbarian P, Fallah-Imani A, 2014. Stimulatory effect of gibberellic acid and benzyladenine on growth and photosynthetic pigments of *Ficus benjamina* L. plants. Int. J. Adv. Biol. Biomed. Res. 2(1): 34-42.

Sarkar PK, Haque MS, Karim MA, 2002. Growth analysis of soybean as influenced by GA_3 and IAA and their frequency of application. Pak. J. Agron. 1(4): 123-126.

Sawant VP, Naik DM, Barkule AM, Shinde SB, 2010. Effect of foliar application plant growth regulators on growth, yield and quality of cabbage cv. Golden Acre. Asian J. Horti. 5 (2): 495-497.

Sharaf–Eldin MA, Schnitzler WH, Nitz G, Razin AM, El–Okash II, 2007. The effect of gibberellic acid (GA_3) on some phenolic substances in globe artichoke (*Cynara cardunculus* var. *scolymus* (L.) Fiori). Sci. Hortic. 111(4): 326-329.

Singh M, Rana DK, Rawat JMS, Rawa SS, 2011. Effect of GA_3 and kinetin on growth, yield and quality of sprouting broccoli (*Brassica oleracea* var. italica). J. Horti. Forest. 3(9): 282-285.

Steel RGD, Torrie JH, 1980. Principles and Procedures of Statistics, Second edition, New York: McGraw-Hill. Book Co. Tokyo, Japan.

Xu S, Li B, 1988. Managing hybrid rice seed production. Proceedings of the 1st international symposium on hybrid rice, Oct. 6-10. *International Rice Research Institute*, Manila, Philippines, pp: 157-163