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Study of Effect of Plant Growth Regulating Hormones for Mitigating Heat Stress in Wheat

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Low productivity (2680 Kg/hectare) (Directorate of Agriculture, Govt. of Bihar; 2012-13) in Bihar is mainly due to late sowing of wheat coupled with prevalent of hot westerly wind during grain filling stage. The wheat production in the state can be increased by two means, either by horizontal expansion or by vertical expansion i.e. by using an improved variety or use of antioxidant or growth regulators to cope heat stress in delayed sown condition. Mitigation of elevated temperature on late sown wheat through genetic intervention is underway at many research station. Study of plant growth regulators in overcoming this abiotic stress of elevated temperature during the reproductive stage of wheat is of great importance.

The present investigation was carried out at DRPCAU, Pusa Bihar during *Rabi* 2016-2017, with five plant growth regulating hormones*viz.,* Glycine betaine (600PPM) (T_2), Salicylic acid (800PPM) (T_3), Salicylic acid (400 PPM) (T_4), Ascorbic acid (10 PPM)(T_5), Tocopherol (150 PPM) (T_6) and control (T_1) on two varieties HD-2733 (normal sown condition) and HD-2985 (late sown condition) with objective to access induced variation and differential influence created on fifteen agro-morphological traits including yield and seed quality attributes.

Different statistical tool undertaken for analysis revealed highly significant differences among entries in respect of fifteen different the agro-morphological traits under study in both conditions *i.e.* normal and late sown conditions.

Treatment T_2 i.e., Glycine betaine (600 PPM), showed a significant effect on highest grain yield per

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plant via, different agro-morphological character mentioned above for normal and delayed sown condition. Yield enhancement due to effect of Treatment T_2 Glycine betaine (600 PPM) was recorded 41.30% higher under normal sown condition whereas 44.92% higher under a late sown condition in comparison to control.

On seed quality traits also showed a significant positive effect of Treatment T_2 Glycine betaine (600 PPM) was observed for seed germination per cent and viability per cent and no effect on vigour index of seed under both normal and delayed sown condition.

Keywords: Plant growth regulating hormones; agro-morphological traits; normal & late sown conditions; glycine betaine (600ppm); salicylic acid (800ppm); salicylic acid (400 Ppm); ascorbic acid (10 Ppm); tocopherol (150 Ppm); elevated temperature; heat stress.

Research Highlight: *Significant yield enhancement due to effect ofGlycine betaine (600 PPM) (Plant growth regulating hormone) accomplish with a positive effect on seed quality traits such as germination, viability &vigour were recorded under both normal sown condition as well as under late sown condition in comparison to control.*

1. INTRODUCTION

Wheat (*Triticum aestivum* L. em. Thell), a cereal grass of the Graminae (Poacae) family and of the genus Triticum, is the world's largest cereal crop.The world acreage under wheat crop is 240 million hectares with a production of 758.1million tonnes with and yield of 2872 kg ha^{-1} (FAO, Regional office for Asia and the Pacific, Bangkok, 2015-16). However the average yield is quite variable across the world, ranging from less than 1 to over 7 tonnes ha^{-1}. The differences in per hectare yield are due to differences in the level of inputs, agricultural sophistication and agro-climatic conditions. Bihar accounts for 5.94 MT of wheat production from an area of 2.22 lakh hectare area with productivity of 2680 Kg/hectare (Directorate of Agriculture, Govt. of Bihar; 2012-13). Low productivity in Bihar is mainly due to late sowing of wheat coupled with prevalent of hot westerly wind during the grain filling stage.

Wheat production in Bihar can be increased either by horizontal expansion (cultivation in newly/reclaimed land) or by vertical expansion (using an improved variety or use of antioxidant or growth regulators to cope heat stress in delayed sown condition).Scope of horizontal expansion is very limited due to the increase in human endeavour other than agriculture by urbanisation and industrialisation [1].

Lot of genetic interventions is underway worldwide to mitigate elevated temperature during a reproductive stage in late sown wheat especially under Rice-wheat cropping system. Study of plant growth regulators in overcoming this abiotic stress of wheat is of great importance and duly acknowledge in literature.

Wheat *[Triticum aestivum* (L.) em.Thell] is a thermo sensitive crop mostly grown in a temperate environment. In subtropical regions it is cultivated in winter season but it exposed to high-temperature stress at the end of the season *i.e.* at grain filling stage. Heat stress is one of the major limiting factors for growth and productivity in wheat crop, particularly in warmer region. Heat stress is anticipated to become more important in future with climate changes, monsoon irregularities and rice-wheat cropping system which has compelled wheat crop to be subjected to rapidly ascending temperature coupled with hot dry winds. Increasing temperature associated with climate change could negatively affect global wheat yields resulting in potential increases in food insecurity and poverty (Tubiello et al.). Most of the crops including wheat exposed to heat stress during later stages of their life cycle [2] *i.e.* grain filling stage resulting in the development of shriveled grain. Exposure to higher than normal temperature or heat stress reduces yield and decreases quality. There are several impediments to increase wheat production in the warmer areas, of which development of heat tolerant; use of plant growth regulating hormones are the most important one [1].

In India, breeding for high-temperature stress in wheat is becoming important because of fast growing area in North-Western Plains Zone (NWPZ) and North-Eastern Plains Zone (NEPZ) under delayed planting due to rice-wheat crop rotation, where crop is exposed to high temperature stress at the post anthesis phase.

Climate change and biotic stress affect agriculture and crop production adversely. Of the various climatic factors affecting agriculture, the temperature is one of the most important as higher temperatures adversely affect plant growth and yield. Global mean surface temperature increased by 0.5ºC in the twentieth century and is projected to rise in a range from 1.8 to 4.5^{o}C by 2100 (Working group I report, IPCC 2007). An in-depth analysis carried out by Lobell and Field [3], involving the effect of global warming on six major food crops from the year 1982–2002, revealed combined yield loss of around 40 million tonnes for wheat, which accounts for almost half of the yield loss (19 mtper year). At the global level, the demand for wheat is growing at approximately 2 per cent per year. However, genetic gains in yield potential of wheat stand at less than 1 per cent. Consequently, a yield plateau has been observed in the last decade and has been attributed to many factors among which high occurrence of terminal heat stress appears to be the most prominent. Since nearly 90 per cent area under wheat in India has access to irrigation, the yield is limited by supra-optimal temperatures prevailing during various crop growth stages. Almost all stages of wheat growth and development are adversely affected by heat stress. It has long been known that average wheat yield reduces by 4 per cent for every one degree rise in ambient temperature during grain filling. High temperature drastically reduces both yield and quality of wheat. Heat stress induces a decrease in the duration of developmental phases leading to fewer and smaller seeds are significantly contributing to losses of yield [1].

Literature on role of plant growth regulating hormones in mitigating heat stress is available. Salicylic acid (SA) is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plants and act as signal molecule in the induction of defence mechanism [4]. SA has been reported to protect the plants from the heat stress, but the mechanism behind this is not known [5]. It modulates secondary metabolites pathway in plant under abiotic stresses (Morris *et al*. 2000). Khan *et al.* [6] reported that SA interacts with Proline metabolism and ethylene formation to alleviate the adverse effects of heat stress on photosynthesis in wheat. Wang *et al*. [5] reported an increase in the activities of different antioxidant enzymes in wheat treated with foliar SA. Similarly, Janda. (1999) reported that exogenous SA alleviates the damaging effect of various abiotic stresses and modulates the photosynthetic process of the plant.

Ascorbic acid (AsA) is the most abundant and potential antioxidant known in nature (Smirnoff 2000). Exogenous application of various organic compounds has been shown to enhance stress tolerance and significantly contribute to the crop production in the stressed environment [7]. This study was conducted with a hypothesis that exogenous application of AsA enhances the thermotolerance level of wheat under the elevated temperature, through the common mechanisms associated with the heat tolerance antioxidants, osmolytes,

Tocopherol (vitamin E) is synthesised in the plants, mainly concentrated in plastids and acts as an amphiphilic lipid antioxidant. Tocopherol plays a protective role to membrane system in the cell of higher plants [8]; and Wang and Quinn, [9]; assists in maintaining membrane stability [10] and regulates the transport of electrons in the photosystem-II system [11]. Changes in tocopherol levels result from altered expression of pathway-related genes, degradation and, recycling, and it isgenerally assumed that an increase in tocopherol contributes to plant stress tolerance [12], while decreased levels favour oxidative damage. Further, concluded that α-tocopherol can play different roles in plant metabolism and can play important roles in amelioration of biotic and abiotic stresses.

Therefore present investigation will be undertaken to control adverse effect of elevated temperature on seed setting, seed quality and ultimately yield with use plant growth regulators with objective to assess the chemically induced variation in agro-morphological characters of wheat under normal and heat stress condition and to analyze the differential influence of chemical application on phenotypic expression of yield attributing characters under heat stress [1].

2. MATERIALS AND METHODS

The present investigation was carried out in the fields located at Breeder Seed Production Plot in TCA, Dholi, under DRPCAU, Pusa, and Bihar during *Rabi* 2016-2017. The experimental materials of the study comprised of 2 varieties of bread wheat (*Triticum aestivum* L.) namely HD-

2733& HD-2985 and five plant growth regulator hormones namely Glycine betaine (600 PPM), Salicylic acid (800PPM), Salicylic acid (400PPM), Ascorbic acid (10 PPM) and Tocopherol (150 PPM).

The Experiment was sown in Randomized Block Design (RBD) with four replications and two dates of sowing i.e., normal and 30 days delay with two varieties HD-2733 & HD-2985 respectively. In each replication 6 treatment were given namely T_1-control, T_2-Glycinebetaine (600 PPM),T_3-Salicylic acid(800PPM),T_4-Salicylic acid (400PPM),T_5-Ascorbic acid (10 PPM), T_6-Tocopherol (150 PPM)at two stages i.e., first at vegetative and second at reproductive stage of plant. Standard agronomic practices were adopted with 22cm row to row spacing. Five random plants per replication were tagged to record observations on twelve seed yield i.e. Days to flowering, Days to maturity, Plant height (cm), Pollen fertility per cent, Spikelet fertility per cent, Flag leaf area (cm^2), Number of tillers per plant, Ear length (cm), Number of grains per ear, 1000 grain weight (g), Harvest index, Seed yield per plant (g) and yield attributing characters along with three seed quality traits i.e. Seed germination per cent, Vigour Index, Viability per cent.

The statistical analysis of the data on the individual character was carried out on the mean values over four replications. The statistical methods adopted were Mean. Range, Coefficient of Variation, Analysis of variance (ANOVA) for all characters, Correlation coefficient,Path coefficient analysis and Simple Regression coefficient analysis.

3. RESULTS AND DISCUSSION

Analysis of variance revealed highly significant differences among entries in respect of all the agro-morphological traits under studied in both conditions *i.e.*normal and delayed sown condition except for a number of tiller per plant in delayed sown condition.

Effect of different plant growth regulating hormones on mean performance of fifteen agro-morphological traits under normal sown condition showed varied response such as: For days to flowering, T_1 showed the longest duration of 72.05 days under normal sown condition, whereas T_6 acquired the shortest duration of 66.10days. For days to maturity,T_2 recorded shortest duration of 109.32 days followed by T_3(111.52 days)and T_5 (111.02 days).For plant height, T_6 recorded maximum (99.31cm), whereasT_2 recorded shortest plant height .The maximum pollen fertility per cent was exhibited by T_2(77.93) and minimum pollen fertility per cent was exhibited by T_1 (69.71).For spikelet fertility per cent, T_6 recorded highest (90.95%), whereasT_2 recorded lowest value. For flag leaf area, T_1 and T_3 showed highest and lowest value respectively. For number of tillers per plant T_2 showed maximum tillering, whereas T_1 recorded the minimum number of tillers.T_2recorded highest ear length. For number of grains per ear, the maximum value being associated with T_2while minimum value recorded with the T_1.The treatment T_2 recorded the highest 1000 grain weight (46.61) followed by T_6 (43.34). Similarly for harvest index, the highest significant effect being associated with T_2 (48.63%) in compare with control.For seed yield per plant the lowest and highest effect being associated with T_1 (14.36g) and T_2 (20.29g), respectively.

Effect of different plant growth regulating hormones on mean performance of fifteen agro-morphological traits under delayed sown condition showed varied response such as: For days to flowering T_6 results in significant earlier days to flowering than check (T_1). For the traits days to maturity, T_6 recorded shortest days (99.87 days) followed by T_5 (100.27days).For plant height, T_2 recorded maximum (93.13cm), whereas treatment (T_1) recorded shortest plant height.The maximum pollen fertility per cent was exhibited by T_6 (75.27) and minimum pollen fertility per cent was exhibited by T_1(67.72%). Effect of treatment on spikelet fertility per cent, T_2 recorded highest (87.03%), whereas T4recorded lowest spikelet fertility per cent (84.11%). For flag leaf area T_3 and T_1 showed highest and lowest value respectively. Number of tillers per plant also influenced maximum by treatment T_2 whereas T_1) recorded r minimum value for traits.For ear length effect of treatmentT_2 showed recorded maximum value, whereasT_1 recorded r minimum value. For number of grains per ear the maximum value being associated with T_2, while minimum value recorded with T_1. The treatment T_2 recorded highest 1000 grain weight (44.24g) followed by T_1 (34.68g).For harvest index the highest significant effect being associated with the treatment T_2 (48.63%) in compare with control. Effect of treatment T_2 Glycine betaine (600 PPM) (17.14g) also influenced seed yield per plant significantly in compare with control T_1 (11.82g).

Table 1. Analysis of variance for fifteen agro-morphological characters under normal and delayed sowing conditions [1]

	Characters	Mean sum of squares (normal)			Mean sum of squares (delayed)		
		Rep. (d f=3)	Treatment (d f=5)	Error (d f=15)	Rep. (d f=3)	Treatment (d f=5)	Error (d f=15)
1.	Days to Flowering	4.43	18.42*	5.66	10.16	54.1**	11.56
2.	Day to Maturity	1.83	11.70**	3.20	2.84	10.23*	4.24
3.	Plant height	4.34	25.14*	7.72	7.72	42.76*	12.28
4.	Pollen fertility per cent	21.17	33.78*	9.66	15.85	33.5**	8.71
5.	Spikelet fertility per cent	3.13	4.77	3.70	15.92	4.34*	6.11
6.	Flag leaf Area (cm2)	0.052	1.08*	0.42	2.20	1.46*	0.49
7.	Number of tiller Per Plant	0.19	1.32**	0.23	1.52	1.43	0.67
8.	Ear length (cm)	1.38	9.90**	1.60	2.24	10.5**	1.69
9.	Number of grain per ear	7.48	67.63**	15.73	1.17	23.70*	7.83
10.	1000 grain weight (gm)	13.45	70.77**	9.47	8.22	51.47**	11.08
11.	Harvest Index per cent	8.71	56.17**	13.59	14.85	55.60*	15.66
12.	Seed yield per plant	10.24	20.75*	6.60	5.86	16.3**	3.85
13.	Seed germination per cent	3.72	19.15*	5.69	3.56	18.8**	4.67
14.	Seed viability per cent	4.17	15.73**	4.35	2.98	22.9**	5.97
15.	Vigour Index	5971.12	124173.12**	16954.24	10797.75	23893.26	19780.92

Table 2. Mean performance of fifteen agro-morphological traits under normal sowing conditions [1]

SN	Treat.	DF	DM	PH	PFP	SFP	FLA	TPP	EL	GPE	TGW	HI	SYPP	SGP	VP	VI
1	T1	72.05	114.52	98.37	69.71	88.72	19.96	5.81	8.86	39.39	35.91	38.37	14.36	89.80	86.64	1366.04
2	T2	69.24	109.32*	92.98*	77.93*	87.92	19.02	7.42*	13.77*	50.49*	46.61*	48.63*	20.29*	96.04*	92.03*	1478.95
3	T3	69.67	111.62*	95.25	76.06*	90.12*	18.72	6.56*	10.97*	41.65	38.86	40.86	14.92	92.47	90.84*	1385.16
4	T4	71.78	112.25	99.05	74.02	89.04*	19.87	7.09*	11.20*	42.80	36.05	38.75	14.54	91.24	90.97*	1376.16
5	T5	69.71	111.02*	97.99	75.10*	88.92*	19.85	6.27	10.71	40.61	40.35	40.57	15.66	92.98	91.26*	1705.33*
6	T6	66.10*	112.30	99.31	76.90*	90.95*	19.24	6.53*	11.35*	46.07*	43.34*	42.44	17.28	94.17*	91.75*	1758.80*
	Mean	69.76	111.84	97.16	74.95	89.26	19.44	6.61	11.14	43.50	40.19	41.60	16.17	92.78	90.58	1511.75
	Cv	3.41	1.60	2.86	4.14	2.15	3.36	7.35	11.37	9.11	7.65	8.86	15.88	2.57	2.30	8.61
	CD	3.58	2.69	4.18	4.6	3.45	2.34	0.73	1.91	5.97	4.63	5.55	3.87	3.59	3.14	196.24

Table 3. Mean performance for fifteen agro-morphological traits under delayed sowing conditions [1]

SN	Treat.	DF	DM	PH	PFP	SFP	FLA	TPP	EL	GPE	TGW	HI	SYPP	SGP	VP	VI
1	T_1	68.37	102.72	83.91	67.72	84.98	17.15	5.35	7.73	38.51	34.68	36.87	11.82	88.61	84.78	1224.72
2	T_2	64.44	101.19*	93.13	71.92	87.03*	18.11	6.80*	12.75*	44.55*	44.24*	47.47*	17.13*	94.99*	91.45*	1166.55
3	T_3	64.98	102.31*	88.56	74.65*	85.41	18.81*	5.75*	10.02*	40.38	37.58	39.74	12.28	91.71	88.31	1202.44
4	T_4	67.55	104.09	87.08	73.87*	84.11	17.60	5.54*	9.97*	39.91	36.08	37.86	12.10	90.97	87.15	1347.64*
5	T_5	60.29*	100.27*	89.38	75.07*	85.66*	18.06	6.05*	10.22*	40.94	38.53	39.93	13.40	92.87*	89.29*	1350.39*
6	T_6	59.39*	99.87*	91.56	75.27*	86.46*	17.34	6.68*	10.89*	44.21*	41.77*	40.41	14.51	93.09*	90.42*	1228.60*
	Mean	64.17	101.74	88.94	73.08	85.61	17.84	6.03	10.26	41.42	38.81	40.38	13.54	92.04	88.57	1253.39
	Cv	5.29	2.02	3.94	4.04	2.88	3.94	13.59	12.67	6.75	8.57	9.80	14.49	2.34	2.76	11.22

Table 4. Correlated effect of chemical application (Normal)

	DF	DM	PH	PFP	SFP	FLA	TPP	EL	GPE	TGW	HI	SGP	VP	VI
DF														
DM	0.2016													
PH	-0.0320	0.4059*												
PF	-0.5056*	-0.3434	-0.0876											
SFP	-0.2545	0.1571	0.0808	0.2859										
FLA	0.4191*	0.5492**	0.3774	-0.4037	0.0551									
TPP	-0.0751	-0.2980	-0.4821*	0.3446	-0.051	-0.2806								
EL	-0.3244	-0.6302**	-0.2843	0.4019	0.2440	0.4680*	0.5038*							
GPE	-0.4781*	-0.3895	-0.2400	0.4740*	-0.0465	-0.3569	0.4213*	0.5533**						
TGW	-0.4615*	-0.4369*	-0.2333	0.4345*	0.1567	0.4642*	0.3086	0.7416**	0.4394*					
HI	-0.0533	-0.3810	-0.4623*	0.2326	0.0744	-0.2202	0.4659*	0.3089	0.5122*	0.5229**				
SGP	-0.1775	-0.3284	-0.3023	0.1584	0.0502	0.1493	0.4492*	0.4835*	0.2851	0.6508**	0.6710**			
VP	-0.3711	-0.3431	-0.1350	0.4774*	-0.2794	-0.1316	0.4793*	0.4443*	0.2156	0.3545	0.2341	0.4332*		
VI	-0.3636	-0.0638	0.2858	0.1304	-0.1320	0.0604	0.0440	0.1087	0.1881	0.3647	0.2092	0.4246*	0.3270	
SYPP	**-0.0964**	**-0.3114**	**-0.3627**	**0.3319**	**0.1663**	0.1526	**0.4468***	**0.2653**	**0.2589**	**0.4911***	**0.5216****	**0.5783****	**0.1561**	**0.245**

Table 5. Correlated effect of chemical application (Late) [1]

	DF	DM	PH	PFP	SFP	FLA	TPP	EL	GPE	TGW	HI	SGP	VP	VI
DF														
DM	0.5798**													
PH	-0.4224*	-0.2720												
PF	-0.2488	-0.2884	0.2665											
SFP	-0.1997	0.1400	0.1982	0.1082										
FLA	0.1249	0.0788	0.1720	-0.2272	0.0804									
TPP	-0.2712	-0.1332	0.3693	-0.7438**	0.0987	-0.5836**								
EL	-0.3089	-0.0393	0.6104**	-0.1578	0.2145	0.4554*	0.6239**							
GPE	-0.3712	-0.1525	0.7253**	0.1396	0.5419**	0.0910	0.4922*	0.6141**						
TGW	-0.2663	-0.0335	0.5664**	-0.1229	0.2895	-0.2875	0.5258**	0.7078**	0.4143*					
HI	-0.1877	-0.1694	0.3990	0.0738	0.0576	-0.0168	0.3314	0.3517	0.1834	0.5196**				
SGP	-0.3651	-0.3579	0.5606**	0.3940	0.2188	0.1919	0.2627	0.6540**	0.5688**	0.4688*	0.3023			
VP	-0.4799*	-0.4602*	0.7145**	0.5093*	0.3131	-0.2669	0.2981	0.5490**	0.5410**	0.5333**	0.3134	0.6868**		
VI	0.0810	-0.0835	-0.0391	-0.1459	-0.2946	0.1346	-0.1721	-0.0677	-0.2113	-0.1255	-0.4283*	0.0201	0.0441	
SYPP	-0.0868	-0.2191	0.4141*	0.0017	0.0286	0.0348	0.3581	0.3740	0.3934	0.5149**	0.6622**	0.3328	0.2234	0.1668

Table 6. Result of cause and effect - analysis of chemical application under normal condition [1]

	DF	DM	PH	PFP	SFP	FLA	TPP	EL	GPE	TGW	HI	SGP	VP	VI
DF	**0.1816**	0.0366	-0.0058	-0.0918	0.0462	-0.0761	-0.0136	-0.0589	-0.0868	-0.0838	-0.0097	-0.0322	-0.0674	-0.0661
DM	-0.0666	**-0.3302**	-0.1340	0.1134	0.0518	0.1813	0.0984	0.2081	0.1286	0.1442	0.1258	0.1084	0.1133	0.0211
PH	0.0041	-0.0525	**-0.1294**	0.0113	0.0104	0.0488	0.0624	0.0368	0.0311	0.0302	0.0598	0.0391	0.0175	-0.0370
PF	-0.1873	-0.1272	-0.0324	**0.3705**	-0.1059	0.1496	0.1277	0.1489	0.1756	0.1610	0.0862	0.0587	0.1769	0.0483
SFP	0.0715	-0.0441	-0.0227	-0.0803	**0.2809**	-0.0155	-0.0146	0.0685	-0.0131	0.0440	0.0209	0.0141	-0.0785	-0.0371
FLA	0.0332	0.0435	0.0299	-0.0320	0.0043	**-0.0793**	-0.0114	-0.0371	-0.0283	-0.0368	-0.0175	-0.0118	-0.0104	0.0048
TPP	-0.0335	-0.1328	-0.2149	0.1536	-0.0231	0.0643	**0.4457**	0.2245	0.1878	0.1375	0.2077	0.2002	0.2136	0.0196
EL	0.3126	0.6074	0.2740	-0.3873	-0.2351	-0.4510	-0.4855	**-0.9637**	-0.5332	-0.7146	-0.2977	-0.4660	-0.4282	-0.1047
GPE	-0.1026	-0.0836	-0.0515	0.1017	-0.0099	0.0766	0.0904	0.1187	**0.2146**	0.0943	0.1099	0.0612	0.0463	0.0404
TGW	-0.2943	-0.2786	-0.1488	0.2771	0.0999	0.2961	0.1968	0.4730	0.2802	**0.6378**	0.3335	0.4151	0.2261	0.2327
HI	0.0226	0.1620	0.1966	-0.0989	-0.0316	-0.0937	-0.1982	-0.1314	-0.2178	-0.2224	**-0.4253**	-0.2854	-0.0996	-0.0890
SGP	-0.0969	-0.1792	-0.1650	0.0864	0.0273	0.0814	0.2451	0.2638	0.1556	0.3551	0.3661	**0.5456**	0.2363	0.2316
VP	0.0762	0.0704	0.0277	-0.0980	0.0573	-0.0270	-0.0984	-0.0912	-0.0443	-0.0728	-0.0480	-0.0889	**-0.2053**	-0.0671
VI	-0.0173	-0.0030	0.0136	0.0062	-0.0062	-0.0029	0.0021	0.0052	0.0089	0.0173	0.0099	0.0202	0.0155	**0.0475**
SYPP	**-0.0964**	**-0.3114**	**-0.3627**	**0.3319**	0.1663	0.1526	**0.4468**	**0.2653**	**0.2589**	**0.4911**	**0.5216**	**0.5783**	**0.1561**	**0.2450**
SYPP	**-0.0868**	**-0.2191**	**0.4141***	0.0017	**0.0286**	0.0348	**0.3581**	**0.3740**	**0.3934**	**0.5149****	**0.6622****	**0.3328**	**0.2234**	0.1668
R^2	**0.6755**													

Table 7. Result of cause and effect - analysis of chemical application under delayed condition

	DF	DM	PH	PFP	SFP	FLA	TPP	EL	GPE	TGW	HI	SGP	VP	VI
DF	**0.2236**	0.1296	-0.0944	0.0556	-0.0446	-0.0279	-0.0606	-0.0691	-0.0830	-0.0595	-0.0420	-0.0816	-0.1073	-0.0181
DM	-0.1793	**-0.3093**	0.0841	-0.0892	-0.0433	0.0244	0.0412	0.0122	0.0472	0.0104	0.0524	0.1107	0.1423	-0.0258
PH	0.1330	0.0856	**-0.3149**	0.0839	-0.0624	0.0542	-0.1163	-0.1922	-0.2284	-0.1784	-0.1257	-0.1765	-0.2250	-0.0123
PF	0.0027	0.0032	-0.0029	0.011	-0.0012	0.0025	0.0013	-0.0017	-0.0015	-0.0014	-0.0008	-0.0044	-0.0056	0.0016
SFP	0.0525	-0.0368	-0.0521	0.0284	**-0.2627**	0.0211	-0.0259	-0.0564	-0.1424	-0.0761	-0.0151	-0.0575	-0.0822	-0.0774
FLA	-0.0023	-0.0014	-0.0031	0.0041	-0.0015	0.0183	-0.0047	-0.0083	-0.0017	-0.0053	0.0003	-0.0035	-0.0049	0.0025
TPP	0.0521	0.0256	-0.0710	-0.0223	-0.0190	0.0495	**-0.1922**	-0.1199	-0.0946	-0.1011	-0.0637	-0.0505	-0.0573	-0.0331
EL	0.0256	0.0033	-0.0505	0.0131	-0.0177	0.0377	-0.0516	**-0.0827**	-0.0508	-0.0586	-0.0291	-0.0541	-0.0454	-0.0056
GPE	-0.3235	-0.1329	0.6320	-0.1216	0.4722	-0.0793	0.4289	0.5351	**0.8715**	0.3611	0.1599	0.4957	0.4714	0.1841
TGW	-0.1310	-0.0165	0.2788	-0.0605	0.1425	-0.1415	0.2588	0.3483	0.2039	**0.4922**	0.2557	0.2307	0.2625	0.0618
HI	-0.1276	-0.1152	0.2712	-0.0502	0.0392	0.0114	0.2253	0.2390	0.1247	0.3532	**0.6797**	0.2055	0.2130	0.2911
SGP	0.0328	0.0321	-0.0503	0.0354	-0.0196	0.0172	-0.0236	-0.0587	-0.0511	-0.0421	-0.0271	**-0.0898**	-0.0616	0.0018
VP	0.1372	0.1316	-0.2043	0.1456	-0.0895	0.0763	-0.0852	-0.1570	-0.1547	-0.1525	-0.0896	-0.1964	**-0.2859**	0.0126
VI	0.0175	-0.0181	-0.0085	-0.0316	-0.0638	-0.0291	-0.0372	-0.0146	-0.0457	-0.0272	-0.0927	0.0043	0.0095	0.2164
SYPP	**-0.0868**	**-0.2191**	**0.4141**	0.0017	**0.0286**	0.0348	**0.3581**	**0.3740**	**0.3934**	**0.5149**	**0.6622**	**0.3328**	**0.2234**	0.1668
R^2								**0.7279**						

Table 8. Simple Regression coefficient on seed yield of different chemically induced traits under the timely sown condition

Character	Beta	R square	Reg. Coeff.	Std .Error	Significance
D M	-0.3003	0.0935	-0.4336	0.3282	
P F P	0.3490	0.1158	0.2746	0.1748	
S F P	-0.2862	0.0477	-0.4640	0.3165	*
T PP	0.5045	0.2254	2.4393	1.1047	**
E L	-0.8103	-0.2149	-1.4041	0.6220	*
T G W	0.4722	0.2319	0.3116	0.2217	**
H I	-0.2207	-0.1151	-0.1493	0.1773	*
S G P	0.5286	0.3057	0.5824	0.3061	
S V P	-0.2600	-0.0406	-0.3177	0.2723	
		R^2	**0.9393**		

Table 9. Simple Regression coefficient on seed yield of different chemically induced traits under delayed sown condition

Character	Beta	R square	Reg. Coeff.	Std .Error	significance
DFF	0.283	-0.0225	0.163	0.107	
D M	-0.385	0.084	-0.434	0.219	
G P E	0.483	0.190	0.391	0.156	*
T G W	0.321	0.165	0.190	0.118	*
H I	0.627	0.415	0.333	0.101	*
S V P	-0.456	-0.102	-0.391	0.187	*
S V I	0.209	-0.035	0.004	0.003	
R^2				**0.9035**	

Correlation studies revealed that grain yield showed significant positive correlation with number of tillers per plant, 1000 grain weight, harvestindex and seed germination per cent under normal sown condition, whereas with plant height, 1000 grain weight and harvest index under delayed sown condition.

Study of cause and effect analysis under normal sown condition also revealed that grain yield per plant were directly positive associated with number of tiller per plant, pollen fertility per cent, spikelet fertility per cent and number of grain per ear whereas showed positive association with days to flowering, pollen fertility per cent, flag leaf area, number of grain per ear, 1000 grain weight, harvest index and vigour index, in delayed sown condition.

The regression of seed yield on fifteen agro-morphological traits *like,* days to maturity, pollen fertility per cent, spikelet fertility per cent, number of tiller per plant, ear length, 1000 grain weight, harvest index, seed germination per cent and viability per cent recorded maximum values of R^2 (0.9393) under normal sown condition [1]. While under the delayed sown condition, the traits like*,* days to flowering, days to maturity, number of grain per ear,1000 grain weight, harvest index and viability percent recorded maximum values of R^2 (0.9035). Hence, selection based on these characters would be more effective for yield improvement.

4. CONCLUSION

In conclusion, out of five plant growth regulating hormones, the effect of treatment T_2 Glycinebetaine (600 PPM), showed a significant effect on highest grain yield per plant via, a different agro-morphological character mentioned above for both normal and delayed condition. Yield enhancement due to effect of treatment T_2 Glycinebetaine (600 PPM) was recorded 41.30% higher under normal sown condition whereas 44.92% higher under a delayed sown condition in comparison to control T1. Seed quality traits also showed a significant positive effect of Glycine betaine (600 PPM) for seed germination per cent and viability per cent and no effect on vigour index of seed under both normal and delayed sown condition.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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