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Study of growth, phenology and bulb yield in garlic (*Allium sativum* L.) genotypes under Malwa plateau of Madhya Pradesh

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Abstract
The present field experiment entitled "Evaluation of different genotypes of garlic (*Allium sativum* L.) under Malwa Plateau of Madhya Pradesh" conducted at College of Horticulture, Mandsaur, (M.P.) during the *Rabi* season 2018-19. The investigation was carried out with 25 genotypes includes 17 local collections and 8 released varieties were studied. The research experiment was laid out in simple Randomized Block Design in three replications during the year 2018-19. The analysis of variance revealed significant difference in all the growth parameters among the genotypes. However, the genotypeT_4 G-282 was recorded highest leaf area (31.29, 64.42, 85.85, 159.88 and 167.88 cm^2 $plant^{-1}$), leaf area index (0.32, 0.5, 0.82 and 1.09), leaf area duration (4.79, 7.51, 12.29 and 11.56 cm^2 day^{-1}) at all the growth phases of the plant. Maximum CGR and RGR recorded in the genotypes T_{15} MDS local-6 at 30-60 DAS (0.64 and 35.71), T_4 G-282 at 60-90 DAS (1.65 and 66.81) and at 120-harvest (6.09 and 144.19), while T_{10} MDS local-1 at 90-120 DAS (2.98 and 86.87). The genotype T_4 G-282 is superior in chlorophyll content (56.53, 68.03, 88.90, 91.79 and 83.40 SPAD), fresh weight of plant (8.57, 17.12, 56.36, 93.50 and 132.47 g) at 30, 60, 90, 120 and harvest respectively, and maximum bulb yield (173.04 q ha^{-1}). In the phenological parameters, genotypes T_{21} Ratlam local (4.00), T_{17} MDS local-8 (4.00) and T_3 G-50 (4.00) were found to be early emergence, T_4 G-282 (6.00) early germination andT_{25} Neemuch local-3 (138.00), T_{24}Neemuch local-2 (138.00) early mature as compare to other genotypes.

Keywords: Garlic, growth, phenology and yield

Introduction
Garlic (*Allium sativum* L.) is the second most widely cultivated bulb crop after onion and belongs to the family Alliaceae. It has been recognized as a valuable spice and condiment throughout India. Garlic is believed to have originated from Semi-Arid areas of Central Asia. Garlic has high nutritive value. It has been considered as a rich source of carbohydrates, proteins and phosphorus. Ascorbic acid content was reported to be very high in green garlic. The uninjured bulb contains a colour less, odorless and water soluble amino acid called "Alien" and converted in to "Allicin" after crushing the bulb of which the principle ingredient is the odoriferous Diallyldisulphide. Garlic contains moisture 62.8%, protein 6.3%, fat 0.1%, Fiber 0.80%, mineral matter per 1.00%, carbohydrate 29%, Phosphorus 0.31%, Calcium 0.03%, Iron 0.001%, per 100g. It also contains vitamin A 175 I.U., vitamin B 0.68% and vitamin B_2 0.08% in dehydrated garlic powder (Kumar *et al*. 2017) [7].
Garlic is grown globally, but China is the largest producer of garlic accounting for 82.86% of world output (APEDA, 2014) [2] India is second largest producer of garlic in world. Garlic occupies 274.10 thousand hectares in our country with annual production of about 1271 thousand tones (NHB, 2017) [12]. Madhya Pradesh is the leading producing state, accounting 92.5 thousand hectares area and 405 thousand tonnes of production of garlic (NHB, 2017) [12]. The other major garlic producing states are Gujarat, Rajasthan, Odisha, Uttar Pradesh and Maharashtra.
The production and productivity of garlic not only depends on area and cultural practices but also on improved high yielding genotypes and environmental conditions (Lawande *et al*. 2009) [8]. The lack of genotypes with high yield with better storage potential are the main constraints limiting the productivity in India, that is why, the average productivity of garlic in India is very low as compared to other countries. Therefore, the present evaluation was undertaken to select genotypes having high bulb yield with large sized cloves per bulb (Aslam *et al*., 2016) [3].

Materials and Methods

The field experiment was carried out at the "Horticulture Research Farm" College of Horticulture Mandsaur, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.) during *rabi* season of 2018-19with Randomized Block Design which replicated thrice. This investigation was carried out with 25 genotypes which include 17 local collected genotypes from the Mandsaur, Neemuch, Ratlam, Vidisha and Sehore district of Madhya Pradesh, Kota district of Rajasthan and 8 released varieties from different centers. All the morphological and growth parameters were recorded at 30, 60, 90, 120 DAS and at harvest to recorded all the parameters and later on their mean was calculated. The experimental data were subjected to statistical analysis using analysis of variance technique suggested by Panse and Sukhatme (1985) [14]. Where the "F" test was found significant at 5% level of significance, the critical differences for the treatments comparison were worked out.

Result and Discussion

The result revealed that, all the parameters were significantly differed among genotypes in relation to growth, phenological and yield parameters during investigation at all the growth intervals and all the attributes are presented in Table1, 2 and 3.

The growth parameters like leaf area, leaf area index, leaf area duration, crop growth rate, relative growth rate, SPAD value, fresh weight and yield parameter like bulb yield (q ha^{-1}) were varied significantly among the genotypes. The growth characters in relation to growth characteristic at all the plant growth intervals at 30, 60, 90, 120 and at harvest. The present study revealed that, the genotypes T_4 G-282 was recorded highest leaf area (31.29, 64.42, 85.85, 159.88 and 167.88 cm^2), leaf area index (0.32, 0.5, 0.82 and 1.09) and leaf area duration (4.79, 7.51, 12.29 and 11.56 cm^2 day^{-1}) at all the growth phases of the plants. The variation recorded the vigorous growth in garlic means production of more leaves, which helped in the synthesis of more photosynthesis and thus resulting in increased accumulation of carbohydrates and other metabolites, which ultimately determined the size and weight of leaf. It may be due to large size of the leaves, also maximum photo synthetically active surface and more number of leaves which leads to maximum leaf area that intern increases the leaf area index and leaf area duration (Silabut, 2013).The present study revealed that, the maximum CGR and RGR was recorded in the genotype T_{15} MDS local-6 (0.64 and 35.71) at 30-60 DAS, T_4 G-282 (1.65 and 66.81) at 60-90 DAS and (6.09 and 144.19) 120 DAS-at harvest, while T_{10} MDS local-1 (2.98 and 86.87) at 90-120 DAS. It may be due to genetic make-up of the variety response of genotypes to the climatic and agronomic interaction, genetic characteristics of genotypes and also maximum leaf area results in more absorption of radiant energy which leads to maximum accumulation of dry matter content of the plant and the varietal differences amongst these growth analysis parameters attributed to the variability in the genetic inheritance among the genotypes. According to Srivastava *et al.*, (1999) [16], Silabut (2013) and Om prakash (2017) [13]. The study confirmed that, T_4 G-282 had maximum (8.57, 17.12, 56.36, 93.50 and 132.47 g) fresh weight of plant at 30, 60, 90, 120 DAS and at harvest respectively. It may be due to the plant suitability of genotypes for particular environmental condition and also the plants have a capacity to synthesize more photosynthesis. These results are in accordance with the findings of Kadu *et al.* (2005) [5], Umamahesheswarappa *et al.* (2014) [17] and Nandini *et al.* (2018) [11] in garlic. The study confirmed that, genotype T_4 G-282 (56.53, 68.03, 88.90, 91.79 and 83.40) recorded higher chlorophyll content (SPAD value), at 30, 60, 90, 120 and at harvest. It may be due to genetic makeup of the genotypes. A similar finding was reported by (Monu, 2018) [10] in garlic. The maximum bulb yield (q ha^{-1}) were recorded in the genotype T_4 G-282 (173.04). The reason for the variation due to the highest yield of bulb from these genotypes can be attributed to maximum plant height, leaf number and leaf length as they have physiological capacity to mobilize and translocation photosynthesis to organ of economic value which in turn might have increased the bulb yield. According to Mishra and Vikram (2017) [9], Nandini *et al.* (2018) [11].

A significant difference was noted in all the phonological parameters among the genotypes. The minimum days to emergence was recorded in the genotypesT_{21} Ratlam local (4.00), T_{17}MDS local-8 (4.00) and T_3 G-50 (4.00) whereas, maximum days to emergence took in the genotypes T_{19} MDS local-10 (8.33). It may be due to climatic conditions like temperature, rainfall and relative humidity. Similar results obtained accordance with the findings of Gupta *et al.* (2007) [4] and Anwar and Gouda *et al.* (2007 and 2012).The genotype T_4 G-282 (6.00) took minimum days for 50% germination, while it was maximum days for 50% germination recorded in genotypes T_{19} MDS local-10(13.00). It may be due to the variation in the climatic conditions. These findings are in accordance with the results of Mishra and Vikram (2017) [9] in garlic. The genotype T_{25} Neemuch local-3 (138.00) and T_{24} Neemuch local-2 (138.00) took minimum days to maturity and the maximum in T_2 G-41 (147.00). The variation is may be due to genetic makeup of the genotypes. Generally late maturity was associated with higher economic yield in most of the crops. These results get supported from the results of Panse *et al.* (2013) [15] and Kowser *et al.* (2017) [6] in garlic.

Table 1: Mean performance of garlic genotypes for Leaf area, Leaf area index, Leaf area duration and Crop growth rate

Genotypes	Leaf area (cm^2 $plant^{-1}$)					Leaf area index				Leaf area duration (cm^2 day^{-1})				Crop growth rate (mg cm^2 of ground area day^{-1})			
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest	30-60 DAS	60-90 DAS	90-120 DAS	120 DAS-At harvest	30-60 DAS	60-90 DAS	90-120 DAS	120 DAS-At harvest	30-60 DAS	60-90 DAS	90-120 DAS	120 DAS- at harvest
T_1 G-1	28.24	44.31	80.63	129.65	137.65	0.24	0.42	0.70	0.89	3.63	6.25	10.51	9.36	0.54	1.40	1.76	3.67
T_2 G-41	25.26	37.25	52.79	122.07	130.11	0.21	0.30	0.58	0.84	3.13	4.50	8.74	11.35	0.33	1.03	1.07	4.77
T_3 G-50	27.36	60.96	81.80	153.60	161.60	0.29	0.48	0.78	1.05	4.42	7.14	11.77	11.56	0.34	1.62	2.20	3.84
T_4 G-282	31.29	64.42	85.85	159.88	167.88	0.32	0.50	0.82	1.09	4.79	7.51	12.29	11.10	0.55	1.65	2.48	6.09
T_5 G-323	26.61	36.14	71.20	117.44	125.44	0.21	0.36	0.63	0.81	3.14	5.37	9.43	10.52	0.35	0.79	1.54	3.93
T_6 G-189	25.82	32.21	70.08	103.88	111.88	0.19	0.34	0.58	0.72	2.90	5.11	8.70	9.35	0.33	0.90	1.46	3.03
T_7 Bhima purple	25.03	48.55	56.97	107.23	115.23	0.25	0.35	0.55	0.74	3.68	5.28	8.21	8.53	0.42	0.98	1.45	1.90
T_8 Bhima omkar	24.13	31.60	58.15	126.85	134.52	0.19	0.30	0.62	0.87	2.79	4.49	9.25	10.02	0.33	1.16	1.15	1.72
T_9 Kota local	17.59	45.22	69.45	112.60	120.60	0.21	0.38	0.61	0.78	3.14	5.73	9.10	8.55	0.35	1.13	1.74	1.03

T_{10} MDS local-1	16.11	50.18	74.16	128.66	136.66	0.22	0.41	0.68	0.88	3.31	6.22	10.14	8.11	0.54	0.82	2.98	0.73
T_{11} MDS local-2	19.76	51.75	56.78	92.88	100.88	0.24	0.36	0.50	0.65	3.58	5.43	7.48	6.46	0.42	0.98	1.43	1.73
T_{12} MDS local-3	20.26	54.72	55.04	123.16	131.16	0.25	0.37	0.59	0.85	3.75	5.49	8.91	8.48	0.60	1.02	2.56	0.79
T_{13} MDS local-4	16.83	52.60	65.50	98.81	106.81	0.23	0.39	0.55	0.69	3.47	5.91	8.22	6.85	0.53	0.90	2.68	3.23
T_{14} MDS local -5	18.99	52.45	78.45	97.94	105.94	0.24	0.44	0.59	0.68	3.57	6.54	8.82	6.80	0.45	1.04	1.74	3.94
T_{15} MDS local-6	14.19	59.10	65.83	133.95	141.95	0.24	0.42	0.67	0.92	3.66	6.25	9.99	9.20	0.64	0.57	2.18	1.46
T_{16} MDS local-7	19.84	51.14	69.88	105.58	113.55	0.24	0.40	0.58	0.73	3.55	6.05	8.77	7.43	0.49	1.00	1.81	3.94
T_{17} MDS local-8	17.20	35.14	84.44	117.33	125.33	0.17	0.40	0.67	0.81	2.62	5.98	10.09	7.41	0.62	1.05	1.54	2.26
T_{18} MDS local-9	21.44	48.86	55.35	123.81	131.81	0.23	0.35	0.60	0.85	3.52	5.21	8.96	9.37	0.49	0.84	2.38	1.09
T_{19} MDS local-10	16.82	49.29	64.15	123.48	131.48	0.22	0.38	0.63	0.85	3.31	5.67	9.38	8.50	0.47	0.93	1.50	1.39
T_{20} Vidisha local	22.29	43.74	58.36	115.31	123.64	0.22	0.34	0.58	0.80	3.30	5.10	8.68	7.96	0.47	0.87	1.52	1.93
T_{21} Ratlam local	23.58	54.07	64.09	114.45	122.45	0.26	0.39	0.60	0.79	3.88	5.91	8.93	7.24	0.61	0.75	1.33	2.73
T_{22} Sehore local	19.24	56.19	78.32	125.66	133.66	0.25	0.45	0.68	0.86	3.77	6.73	10.20	7.92	0.33	1.02	2.04	4.58
T_{23} Neemuch local-1	22.83	57.31	79.63	108.66	116.66	0.27	0.46	0.63	0.75	4.01	6.85	9.41	6.89	0.63	1.07	1.09	2.08
T_{24} Neemuch local-2	23.03	53.94	71.18	103.42	111.42	0.26	0.42	0.58	0.72	3.85	6.26	8.73	6.45	0.57	1.36	1.90	3.10
T_{25} Neemuch local-3	11.53	30.71	52.46	90.80	98.80	0.14	0.28	0.48	0.63	2.11	4.16	7.16	5.69	0.27	0.94	1.19	2.27
SEm(±)	0.82	1.35	2.19	3.40	3.73	0.005	0.008	0.012	0.019	0.075	0.120	0.184	0.198	0.050	0.103	0.214	0.321
CD @ 5%	2.32	3.84	6.23	9.68	10.61	0.014	0.023	0.035	0.053	0.214	0.340	0.524	0.564	0.143	0.292	0.608	0.912

Table 2: Mean performance of garlic genotypes for Relative growth rate, Chlorophyll content, fresh weight and Bulb yield

Genotypes	Relative growth rate (mg g^{-1} day^{-1})				Chlorophyll content (SPAD value)					Fresh weight (g $plant^{-1}$)					Bulb yield (q ha^{-1})
	30-60 DAS	60-90 DAS	90-120 DAS	120 DAS-at harvest	30 DAS	60 DAS	90 DAS	120 DAS	At harvest	30 DAS	60 DAS	90 DAS	120 DAS	At harvest	
T_1 G-1	30.12	61.76	68.80	116.73	56.05	58.57	86.93	74.53	81.41	6.63	16.67	51.98	81.83	77.13	169.93
T_2 G-41	13.23	51.14	52.42	110.03	53.77	57.52	80.28	82.22	74.78	4.80	9.05	37.60	50.66	63.17	165.33
T_3 G-50	14.07	66.55	76.45	115.58	56.09	60.44	87.17	80.05	82.00	7.33	16.43	53.48	84.17	106.70	171.70
T_4 G-282	25.91	66.81	80.37	144.19	56.53	68.03	88.90	91.79	83.40	8.57	17.12	56.36	93.50	132.47	173.04
T_5 G-323	15.39	42.71	64.75	105.02	56.03	54.72	68.58	72.83	63.08	5.47	8.32	41.09	80.40	58.77	171.56
T_6 G-189	13.83	46.56	62.75	95.01	55.92	47.80	82.96	77.65	77.49	5.27	8.49	41.93	80.40	57.30	170.81
T_7 Bhima purple	21.73	49.86	62.81	82.25	54.08	56.52	79.61	86.50	74.11	4.21	11.63	26.87	67.91	64.77	164.00
T_8 Bhima omkar	13.26	55.19	54.85	76.73	53.92	56.95	79.41	83.15	73.35	4.19	8.87	27.23	71.33	56.00	162.07
T_9 Kota local	15.20	54.41	68.99	55.92	48.38	56.44	72.27	89.06	66.77	3.25	12.74	39.61	73.99	67.64	137.33
T_{10} MDS local-1	30.20	43.91	86.87	38.38	44.61	53.71	69.65	77.55	64.32	2.44	13.38	42.50	54.50	60.60	127.41
T_{11} MDS local-2	21.76	49.46	62.25	82.47	49.80	55.49	69.61	89.11	63.47	3.37	13.41	38.34	51.50	60.93	139.70
T_{12} MDS local-3	33.47	51.20	81.70	41.08	50.49	54.20	85.47	70.65	79.97	3.67	15.27	46.11	78.67	59.17	141.63
T_{13} MDS local-4	29.34	46.06	80.66	101.88	47.60	57.49	82.16	73.22	76.56	3.02	11.80	39.95	55.67	71.67	134.07
T_{14} MDS local -5	23.96	51.63	68.80	123.93	49.35	51.43	78.67	76.59	73.27	3.29	12.62	40.77	68.23	56.77	137.63
T_{15} MDS local-6	35.71	31.54	76.45	73.92	43.21	50.59	79.71	83.91	74.21	2.23	13.87	44.91	78.85	62.50	128.15
T_{16} MDS local-7	26.21	50.31	70.31	122.73	50.47	61.37	76.32	80.54	70.82	3.50	10.75	35.25	74.78	64.47	141.04
T_{17} MDS local-8	34.42	51.59	64.40	100.13	47.10	58.84	66.69	85.80	61.19	3.09	16.23	37.47	63.95	63.45	135.11
T_{18} MDS local-9	26.50	43.57	79.06	58.38	51.72	59.74	70.29	85.93	64.79	3.68	13.42	33.74	72.67	65.23	143.41
T_{19} MDS local-10	25.04	47.42	63.09	70.33	47.49	61.84	67.92	74.41	62.42	2.63	13.21	39.61	47.49	63.50	128.74
T_{20} Vidisha local	25.31	45.41	64.29	88.11	51.76	58.64	85.61	78.00	80.11	4.17	10.78	32.33	64.65	62.17	149.63
T_{21} Ratlam local	33.88	39.30	59.06	110.34	53.16	56.67	83.56	87.64	78.06	4.03	8.95	49.43	57.33	68.83	155.85
T_{22} Sehore local	13.19	49.86	73.82	138.79	49.49	56.68	76.01	77.42	70.71	3.33	8.60	45.34	64.15	71.83	137.85
T_{23} Neemuch local-1	34.92	52.83	53.11	95.33	51.45	53.47	79.47	70.27	73.97	3.89	15.97	42.04	45.50	58.73	149.93
T_{24} Neemuch local-2	31.92	60.59	71.93	118.67	51.81	56.79	68.15	86.58	62.65	3.93	16.27	45.13	69.68	73.53	151.48
T_{25} Neemuch local-3	6.89	48.03	56.27	100.90	38.85	52.61	62.47	69.55	56.97	2.62	8.53	22.48	41.70	55.90	122.07
SEm(±)	3.337	3.623	3.479	6.698	1.79	1.39	2.32	2.39	2.11	0.17	0.42	1.30	2.01	4.46	4.33
CD @ 5%	9.487	10.300	9.892	19.044	5.08	3.95	6.59	6.79	6.01	0.48	1.20	3.69	5.72	12.69	12.31

Table 3: Mean performance of garlic genotypes for Days to emergence, Days to 50% germination and Days to maturity

Genotypes	Days to emergence	Days to 50% germination	Days to maturity
T_1 G-1	7.00	9.00	141.00
T_2 G-41	6.67	9.00	147.00
T_3 G-50	4.00	7.00	142.00
T_4 G-282	5.00	6.00	140.33
T_5 G-323	6.67	10.00	146.00
T_6 G-189	6.67	9.00	146.00
T_7 Bhima purple	8.00	10.67	143.00
T_8 Bhima omkar	7.33	9.67	143.00
T_9 Kota local	5.33	9.00	142.00
T_{10} MDS local-1	6.00	10.00	138.33
T_{11} MDS local-2	6.00	7.67	140.00
T_{12} MDS local-3	6.00	7.67	140.00
T_{13} MDS local-4	5.33	7.00	140.00
T_{14} MDS local -5	6.67	10.00	140.00

T_{15} MDS local-6	4.67	8.00	140.00
T_{16} MDS local-7	6.33	10.00	140.33
T_{17} MDS local-8	4.00	9.00	138.33
T_{18} MDS local-9	4.33	10.33	142.00
T_{19} MDS local-10	8.33	13.00	140.00
T_{20} Vidisha local	4.33	8.00	140.00
T_{21} Ratlam local	4.00	7.00	138.33
T_{22} Sehore local	4.67	7.00	138.33
T_{23} Neemuch local-1	4.33	7.67	138.33
T_{24} Neemuch local-2	4.67	8.00	138.00
T_{25} Neemuch local-3	5.00	9.00	138.00
SEm(±)	0.33	0.17	0.73
CD @ 5%	0.93	0.47	2.06

Conclusion

Out of 25 genotypes, T_4 G-282, T3 G-50 and T5 G-323 are best performing genotypes for Growth, Phenology and Bulb yield. On the basis of one year research, it could be concluded that T_4 G-282 and T3 G-50 are the outstanding performance and should be used for further breeding programme in garlic.

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