

Effect of Organic Sources and Fertilizer Levels on Physiological Response of Garlic by using Infrared Gas Analysis (IRGA) in Western Rajasthan, India

Abstract

Crop growth and yields are negatively affected by sub-optimal water supply and abnormal temperatures due to physical damages, physiological disruptions, and biochemical changes. A better understanding of garlic responses to organic and inorganic sources conducted A two years field experiment was conducted at Agricultural Research Farm, SKRAU, Bikaner during Rabi 2020-21 and 2021-22. The experiment comprising total 32 treatment combinations; eight sources of organic materials (Control (M₀), FYM @ 20 t ha⁻¹ (M₁), Groundnut husk (GNH) @ 20 t ha⁻¹ (M₂), Wool waste (WW) @ 20 t ha⁻¹ (M₃), FYM @ 10 t ha⁻¹ + GNH @ 10 t ha⁻¹ (M₄), WW @ 10 t ha⁻¹ + GNH @ 10 t ha⁻¹ (M₅), WW @ 10 t ha⁻¹ + FYM @ 10 t ha⁻¹ (M₆), WW @ 6.67 t ha⁻¹ + FYM @ 6.67 t ha⁻¹ + GNH @ 6.67 t ha⁻¹ (M₇) and four fertilizer levels (Control (F₀), 50% RDF (F₁), 75% RDF (F₂) and 100% RDF (F₃) in split plot design with three replications. Result indicated that maximum improvement in photosynthetic rate was recorded under the wool waste applied @ 20 t ha⁻¹ with 100% recommended dose of fertilizer.

Keywords: Wool waste, FYM, Groundnut husk, fertilizer, Photosynthetic rate

INTRODUCTION

Garlic (*Allium sativum* L.), a member of the family *Alliaceae*, is the premier bulbous crop which is consider in spices and vegetable section. In India, it is commonly known as Lahsun. The primary center of origin of garlic is Central Asia and Southern Europe and secondary center is Mediterranean region [17]. It has higher nutritive value than other bulb crops. It is used for flavoring foods, preparing chutneys, pickles, curry powder, tomato ketchup etc. Its volatile oil has many sulphur containing compounds that are responsible for the strong odor, flavor/aroma, pungency.

Crops respond well to manure and fertilizer applications. However, continuous use of the heavy doses of fertilizers damages the natural ecology and adversely affects the nutrient

recycling and the biological communities in soil which otherwise support the crop production [15]. Plant nutrients play an important role in crop production and use various sources of nutrients, they supply various essential plant nutrients for proper growth and internal metabolic activities in plant body. Application of all essential nutrients through chemical fertilizers are known to have deleterious effect on soil fertility leading to unsustainable yields, while integration of chemical fertilizers with organic manures are able to maintain the good soil health, productivity and fertility status of soil [7].

Rate of plant growth and development is dependent upon the temperature surrounding the plant and each species has a specific temperature range represented by a minimum, maximum, and optimum. These values were summarized by [2,3] for a number of different species typical of grain and fruit production. The temperature response of different species has been evaluated by [10,11,12,13,14,15]. A recent IPCC report indicated, with medium confidence, that crop yields will experience 'severe and widespread impacts' if global warming exceeds 1.5 °C above pre-industrial levels, but that these impacts can be managed below this warming threshold [5]. Atmospheric concentrations of carbon dioxide have been steadily rising, from approximately 315 ppm (parts per million) in 1959 to a current atmospheric average of approximately 385 ppm [8]. Current projections are for concentrations to continue to rise to as much as 500–1000 ppm by the year 2100 [6]. While a great deal of media and public attention has focused on the effects that such higher concentrations of CO₂ are likely to have on global climate, rising CO₂ concentrations are also likely to have profound direct effects on the growth, physiology, and chemistry of plants, independent of any effects on climate [18]. Water is required for processes such as germination, cell division and elongation for the promotion of plant growth in height and width and metabolic activities, such as the synthesis of organic compounds, photosynthesis, respiration and a number of other physiological and biochemical processes [16]. Hence a study was undertaken to assess the effect of organic sources and fertilizer levels on physiological response of garlic in arid region of western Rajasthan.

MATERIAL AND METHODS

Climate and weather conditions

Bikaner has arid climate with average annual rainfall of about 262 mm. More than 80 per cent of rainfall is received during *kharif* season (July-September) by the South West monsoon. During summer, the maximum temperature may go as high as 48 °C while in the winters it may fall as low as 0 °C. The weather data was obtained from meteorological observatory of Agricultural Research Station, Bikaner.

The weather conditions prevailed during the study period were obtained from records of meteorological observatory of ARS, SKRAU. The mean data showed that during growth period of garlic maximum and minimum temperatures fluctuated between 20.3 °C to 35.1 °C and 2.7 °C to 17.9 °C, maximum and minimum relative humidity 53.0 % to 80.4 % and 17.0 % to 48.4 %, respectively during *rabi* 2020-21. The corresponding values were between 18.0 °C to 41.4 °C and 3.1 °C to 19.1 °C temperature and 57.7 % to 91.3 % and 15.1 % to 60.7 % relative humidity during *rabi* 2021-22. During the growth period of garlic in the year *rabi* 2020-21 and *rabi* 2021-22 the total rainfall 3.8 and 39.4 mm, respectively.

Details of experiment and treatments

A two years field experiment was conducted at Agricultural Research Farm, SKRAU, Bikaner during *Rabi* 2020-21 and 2021-22. The experiment comprising total 32 treatment combinations; eight sources of organic materials (Control (M_0), FYM @ 20 t ha⁻¹ (M_1), Groundnut husk (GNH) @ 20 t ha⁻¹ (M_2), Wool waste (WW) @ 20 t ha⁻¹ (M_3), FYM @ 10 t ha⁻¹ + GNH @ 10 t ha⁻¹ (M_4), WW @ 10 t ha⁻¹ + GNH @ 10 t ha⁻¹ (M_5), WW @ 10 t ha⁻¹ + FYM @ 10 t ha⁻¹ (M_6), WW @ 6.67 t ha⁻¹ + FYM @ 6.67 t ha⁻¹ + GNH @ 6.67 t ha⁻¹ (M_7) and four fertilizer levels (Control (F_0), 50% RDF (F_1), 75% RDF (F_2) and 100% RDF (F_3) in split plot design with three replications. The RDF of garlic was 50 kg N, 60 kg P₂O₅ and 100 kg K₂O was applied.

Table 1. Details of the experiment as follows:

Season	<i>Rabi</i> , 2020-21 & 2021-22
Test crop	Garlic
Design	Split Plot Design
Total no. of treatments	
Main Plot	8
Sub Plot	4
Total no. of replications	3

Total no. of plots	96
Row spacing	15 cm
Plant spacing	7 cm
Plot size	5 X 2 M
Seed rate	5 qt clove ha ⁻¹
Variety	Yamuna safed
Location	Instructional Farm ARS, Bikaner

Ten plants were selected from each plot excluding the border row for taking observation. The observations were recorded by Infrared Gas Analyzer 90 day after sowing. Observations recorded different parameters in normal environment as well as stress environment. All the parameters were recorded by Infrared gas analysis (IRGA) model number CI-340. The CI-340 Ultra-Light Portable Photosynthesis System is an improved version of the first light weight, hand-held photosynthesis system in the world. Featuring a new design concept and compact solid-state structure, the entire system display, keypad, computer, data memory, CO₂/H₂O gas analyser, flow control system and battery is contained in a single, hand-held case. Principle of Infrared Gas Analysis is measures heteroatomic trace gases based on the absorption wavelength of infrared (IR) light as it passes through an air sample. Parameters can be recorded by Infrared gas analysis (IRGA) model number CI-340 show in appendix (Table 4). Water use efficiency (WUE) is the ratio of net photosynthesis rate (umol/m²/s) to transpiration rate (mmol/m²/s). Carboxylation efficiency is the ratio of net photosynthesis rate (umol/m²/s) to Internal CO₂ concentration (ppm)

Table 2: Average elemental composition of FYM, groundnut husk and wool waste

Element	Farm yard manure	Groundnut husk	Wool waste
Carbon (%)	20.42	21.09	18.92
Nitrogen (%)	0.702	0.502	2.248
Phosphorus (%)	0.297	0.471	0.285
Potassium (%)	0.392	0.865	0.712
Sulphur (%)	0.06	0.54	2.28
Iron (ppm)	882.15	724.60	882.11
Copper (ppm)	4.88	5.10	12.68
Zinc (ppm)	43.46	24.04	88.12
Manganese (ppm)	58.12	43.30	48.47

RESULT AND DISCUSSION

The present study is conducted to understand the physiological reaction of organic sources and fertilizer levels 32 treatment combinations. Here we discuss effects of these treatment on garlic crop on the basis on net photosynthesis, transpiration rate, Photosynthesis active radiation, leaf temperature, air temperature, inlet CO₂, vapor pressure Deficit, outlet CO₂ inlet relative humidity, outlet relative humidity, outlet water pressure and inlet relative humidity. Table 3 indicated that on the pooled basis maximum photosynthetic rate was recorded under the wool waste applied @ 20 t ha⁻¹ with 50 kg N, 60 kg P₂O₅ and 100 kg K₂O *i.e.*, 100% recommended dose of fertilizer (M₃F₃). It might due to photosynthesis is the formation of carbohydrates from CO₂ and a source of hydrogen (as water) in the chlorophyll containing tissues of plants exposed to light. The rate at which photosynthesis occurs is determined by measuring the rate at which a known leaf area assimilates the CO₂ concentration in a given time. Temperature, carbon dioxide concentration and light intensity can affect the rate of photosynthesis. and this may be owing to increased supply of multi-nutrients, plant growth regulators and beneficial microflora released from wool waste [22,23,24] Its addition to soil creates most favourable conditions and improved with respect to physico-chemical and biological properties of the soil which promoted plant growth by ensuring higher number of greener leaves with increased photosynthesis as a result of increased metabolism of the plant

ultimately increased vegetative parameters as above. Hence now we can say that the organic sources with fertilizer levels increased plant photosynthetic rate as well as physiological response. Similar result reported by [1,4,9,19,20,21].

Conclusion:-

Therefore, it may be concluded on the basis of above investigation that the combination of organic manure and inorganic fertilizer *i.e.* treatment wool waste applied @ 20 t ha⁻¹ with 100% recommended dose of fertilizer (M₃F₃) can be recommended for garlic growers to achieve the better performance under the hyper arid Region of Rajasthan.

UNDER PEER REVIEW

Table 3. Physiological parameters of garlic respond to organic sources with fertilizer levels

Treatment	T air	T leaf	CO ₂ in	CO ₂ out	H ₂ O in	H ₂ O out	RH in	RH out	VPD	E	PAR	Pn	C	int_CO ₂	WUE	Ce
M ₀ F ₀	24.00	23.60	1280.20	1270.70	1.69	2.22	56.40	74.00	0.71	1.76	263.60	3.07	269.03	1260.40	1.74	0.0024
M ₀ F ₁	21.40	21.00	1281.90	1266.10	1.37	1.91	53.50	74.70	0.58	1.81	169.60	5.17	344.41	1255.40	2.86	0.0041
M ₀ F ₂	21.00	21.50	1283.10	1263.80	1.35	1.89	54.30	75.70	0.69	1.80	338.00	6.34	283.75	1244.30	3.52	0.0051
M ₀ F ₃	23.70	24.50	1340.20	1320.10	1.47	2.12	49.80	71.80	0.98	2.15	367.90	6.54	235.43	1292.70	3.04	0.0051
M ₁ F ₀	23.20	23.70	1266.30	1220.30	1.49	2.10	52.40	73.80	0.84	2.02	272.40	15.01	258.70	1166.30	7.43	0.0129
M ₁ F ₁	23.90	23.60	1302.00	1211.20	1.65	2.38	55.60	79.90	0.55	2.42	113.30	29.67	506.52	1194.10	12.26	0.0248
M ₁ F ₂	24.60	24.40	1253.50	1148.20	1.52	2.54	48.80	81.70	0.54	3.42	250.40	34.28	787.13	1167.40	10.02	0.0294
M ₁ F ₃	23.30	22.50	1379.10	1255.20	1.58	2.18	55.00	75.90	0.56	2.00	191.20	40.42	401.54	1198.60	20.21	0.0337
M ₂ F ₀	22.40	22.20	1310.20	1289.40	1.39	2.02	51.10	74.30	0.67	2.10	209.40	6.80	344.83	1275.40	3.24	0.0053
M ₂ F ₁	24.80	24.50	1439.00	1086.40	1.69	1.93	53.80	61.60	1.15	0.09	209.70	12.76	7.78	1100.00	141.78	0.0116
M ₂ F ₂	23.20	23.70	1266.30	1220.30	1.49	2.10	52.40	73.80	0.84	2.02	272.40	15.01	258.70	1166.30	7.43	0.0129
M ₂ F ₃	23.90	23.70	1259.90	1208.10	1.47	2.22	49.40	74.70	0.73	2.49	217.70	16.84	379.43	1180.80	6.76	0.0143
M ₃ F ₀	20.20	20.60	1336.60	1166.90	1.34	1.98	56.30	83.00	0.46	2.13	253.60	55.79	539.13	1144.20	26.19	0.0488
M ₃ F ₁	25.00	25.10	1345.40	1155.90	1.48	2.44	46.60	76.90	0.75	3.19	222.80	61.24	484.36	1113.80	19.20	0.0550
M ₃ F ₂	23.30	21.70	1593.10	1278.10	1.44	2.31	50.10	80.30	0.30	2.89	166.60	102.71	1353.00	1422.40	35.54	0.0722
M ₃ F ₃	25.20	26.30	1655.80	1275.60	1.40	2.24	43.60	69.70	1.19	2.77	219.80	122.43	250.34	814.60	44.20	0.1503
M ₄ F ₀	19.30	18.00	1313.00	1276.20	1.30	1.58	58.00	70.50	0.49	0.95	220.90	12.20	205.20	1212.00	12.84	0.0101
M ₄ F ₁	23.10	22.70	1336.30	1247.60	1.44	2.05	50.70	72.30	0.72	2.05	231.40	29.07	312.04	1173.30	14.18	0.0248
M ₄ F ₂	23.70	22.90	1255.10	1154.30	1.42	1.98	48.40	67.50	0.82	1.87	281.10	32.92	244.15	1023.60	17.60	0.0322
M ₄ F ₃	23.40	23.20	1403.60	1281.20	1.36	2.06	47.00	70.90	0.81	2.31	299.80	39.92	312.85	1180.20	17.28	0.0338
M ₅ F ₀	24.70	24.80	1263.00	1170.90	1.37	2.14	43.80	68.40	1.00	2.54	230.30	29.73	275.07	1075.80	11.70	0.0276
M ₅ F ₁	22.80	22.80	1326.60	1220.20	1.36	2.05	48.50	73.40	0.74	2.32	248.10	34.82	348.84	1150.20	15.01	0.0303
M ₅ F ₂	25.10	25.30	1386.50	1254.10	1.46	2.56	45.60	80.10	0.67	3.65	171.30	42.67	646.49	1260.40	11.69	0.0339
M ₅ F ₃	21.90	21.90	1384.10	1231.70	1.41	1.98	53.50	75.40	0.66	1.93	225.20	50.17	320.25	1109.30	25.99	0.0452
M ₆ F ₀	23.80	23.30	1348.10	1187.40	1.71	2.38	58.00	80.80	0.48	2.24	76.00	52.29	542.42	1168.70	23.34	0.0447
M ₆ F ₁	22.50	22.80	1576.60	1390.20	1.46	2.05	53.30	74.90	0.74	1.97	202.50	60.81	289.84	1211.70	30.87	0.0502
M ₆ F ₂	25.20	24.80	1498.20	1308.10	1.35	2.36	42.00	73.20	0.77	3.33	139.00	61.45	495.33	1270.20	18.45	0.0484
M ₆ F ₃	24.70	24.80	1472.90	1127.40	1.42	2.44	45.30	78.00	0.70	3.45	212.10	113.95	580.26	1104.00	33.03	0.1032
M ₇ F ₀	18.00	18.60	1297.40	1216.00	1.22	1.21	58.80	58.60	0.94	1.85	249.00	27.21	380.00	1200.00	14.71	0.0227
M ₇ F ₁	25.20	25.80	1243.30	1141.60	1.40	2.46	43.60	76.40	0.88	3.50	301.40	32.96	450.83	1110.50	9.42	0.0297
M ₇ F ₂	24.60	24.90	1249.00	1129.60	1.32	2.55	42.70	82.10	0.61	4.08	274.80	38.87	837.36	1156.10	9.53	0.0336
M ₇ F ₃	23.60	22.90	1694.60	1535.60	1.42	2.25	48.50	77.10	0.55	2.78	242.10	51.72	600.08	1531.90	18.60	0.0338

Appendix

Table 4: List of physiological data recorded by Infrared gas analysis (IRGA) model number CI-340.

S.No.	Denoted by	Abbreviation	Unit
1.	Internal T	Internal temperature for the instrument	deg C
2.	Pressure	Atmospheric pressure	kPa
3.	Tair	Air temperature	deg C
4.	CO2in	Inlet CO ₂	ppm
5.	H2Oin	Inlet water pressure	kPa
6.	W	Mass flow rate	mol/m ⁻² /s
7.	E	Transpiration rate	mmol/m ⁻² /s
8.	RHin	inlet relative humidity	%
9.	int CO2	Internal CO ₂ concentration	ppm
10.	Flow	Flow rate	l/min
11.	PAR	Photosynthesis Active Radiation	umol/m ⁻² /s
12.	Tleaf	Leaf temp.	deg C
13.	CO2out	Outlet CO ₂	ppm
14.	H2Oout	Outlet water pressure	kPa
15.	Pn	Net photosynthesis rate	umol/m ⁻² /s
16.	C	Stomatal conductance rate	mmol/m ⁻² /s
17.	RHout	Outlet relative humidity	kPa
18.	VPD	Vapour-pressure deficit	kPa
19.	fluorescence	fluorescence	
20.	Month	Current month	
21.	H, min and s	Time experiments conducted	
22.	Date	Current date	
23.	Year	Current year	

REFERENCES

1. Górecki, R.S. & Górecki, M.T. Utilization of waste wool as substrate amendment in pot cultivation of tomato, sweet pepper, and eggplant. *Polish Journal of Environmental Studies*, 2010: 19(5): 1083-1087.
2. Hatfield, J. L., Boot, K. J., & Kimball, B. A. The effects of climate change on agriculture, land resources, water resources, and biodiversity. *Synthesis and Assessment Product*, 2008:4.
3. Hatfield, J. L., Boote, K. J., Kimball, B. A., Ziska, L. H., Izaurralde, R. C., Ort, D., ... & Wolfe, D. Climate impacts on agriculture: implications for crop production. *Agronomy journal*, 2011: 103(2), 351-370.
4. Indira, P., Lenin, M. & Mycin, T.R. Efficacy of groundnut haulm compost on the growth and yield of blackgram (*Vigna mungo* L.) var. Vamban 1. *Current Botany*, 2010:1(1): 1-3.
5. IPCC. Summary for policymakers. In: Masson- Delmotte, V., Zhai, P, Pörtner HO, et al. , eds. Global warming of 1.5 °C. Geneva, Switzerland: IPCC. 2018
6. IPCC. Climate Change: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. 2007.
7. Jeyabal, A., Palaniappan, S.P. & Chelliah, S. Effect of integrated nutrient management techniques on yield attributes and yield of sunflower (*Helianthus annuus*). *Indian Journal of Agronomy*, 2000:45(2): 384-388.
8. Keeling, C. D., & Whorf, T. P. Atmospheric CO₂ records from sites in the SIO air sampling network. *Trends*, 1994:93, 16-26.
9. Khandelwal, A.K. Efficacy of sheep based organic waste for improving soil health and productivity of Tomato (*Solanum lycopersicum* L.) under shade net house. *M.Sc. thesis*, S K Rajasthan Agricultural University, Bikaner. 2021
10. Prasad, P. V. V., Boote, K. J., Allen Jr, L. H., Sheehy, J. E., & Thomas, J. M. G. Species, ecotype and cultivar differences in spikelet fertility and harvest index of rice in response to high temperature stress. *Field crops research*, 2006:95(2-3), 398-411.
11. Prasad, P. V. V., Craufurd, P. Q., Kakani, V. G., Wheeler, T. R., & Boote, K. J. Influence of high temperature during pre-and post-anthesis stages of floral

- development on fruit-set and pollen germination in peanut. *Functional Plant Biology*, 2001:28(3), 233-240.
12. Prasad, P. V., Boote, K. J., & Allen Jr, L. H. Adverse high temperature effects on pollen viability, seed-set, seed yield and harvest index of grain-sorghum [*Sorghum bicolor* (L.) Moench] are more severe at elevated carbon dioxide due to higher tissue temperatures. *Agricultural and forest meteorology*, 2006:139(3-4), 237-251.
 13. Prasad, P. V., Boote, K. J., Allen Jr, L. H., & Thomas, J. M. Effects of elevated temperature and carbon dioxide on seed- set and yield of kidney bean (*Phaseolus vulgaris* L.). *Global Change Biology*, 2002: 8(8), 710-721.
 14. Prasad, P. V., Pisipati, S. R., Ristic, Z., Bukovnik, U. R. S. K. A., & Fritz, A. K. Impact of nighttime temperature on physiology and growth of spring wheat. *Crop science*, 2008:48(6), 2372-2380.
 15. Prasad, P.H., Mandal, A.R., Sarkar, A., Thapa, U. & Maity, T.K. Effect of bio-fertilizers and nitrogen on growth and yield attributes of bitter melon (*Momordica charantia* L.); *International Conference on Horticulture*, 2009: pp. 738-739.
 16. Taiz, L., & Zeiger, E. *Plant Physiology* Sinauer Associates. Inc., Sunderland, MA. 2006.
 17. Thompson, C.H. & Kelley, C.W. *Vegetable Crops*, Mc Graw Hill Book Co. Inc., New Delhi, 1957: 502.
 18. Ziska, L. H. Rising atmospheric carbon dioxide and plant biology: the overlooked paradigm. *DNA and Cell Biology*, 2008:27(4), 165-172.
 19. Hanif, M., Khan, R., Kiran, J., Haq, I. U., Ali, S., Niaz, Y., ... & Siddique, M. I. Interactive effect of organic and mineral phosphorus on volatile compounds, morphology, and physiology of garlic (*Allium sativum* L.). *Journal of King Saud University-Science*, 2022: 34(8), 102351.
 20. Diriba-Shiferaw, G., Nigussie-Dechassa, R., Kebede, W., Getachew, T., & Sharma, J. J. . Growth and nutrients content and uptake of garlic (*Allium sativum* L.) as influenced by different types of fertilizers and soils. *Science, Technology and Arts Research Journal*, 2013:2(3), 35-50.
 21. Kenea, F. T., & Gedamu, F. Response of garlic (*Allium sativum* L.) to vermicompost and mineral N fertilizer application at Haramaya, Eastern Ethiopia. *African Journal of Agricultural Research*, 2018:13(2), 27-35.
 22. Oo, A. L., Khine, T. M., & Aye, T. T. Preparation and characterization of organic fertilisers made from bat guano, rice husk ash and groundnut leaves. *Journal Myanmar Academy of Arts and Sciences*, 2019:17(1B), 393-405.

23. ABD RAHMAN, S. S. N., TINGGA, R. C. T., BUKHORI, M. F. M., & ABDULLAH, S. M. A. A. . A Brief Review of the Nutritive Value and Chemical Components of Bat Guano and Its Potential Use as a Natural Fertiliser in Agriculture. *Borneo Journal of Resource Science and Technology*, 2023:13(1), 22-31.
24. Nackley, L. L., Jeong, J. H., Oki, L. R., & Kim, S. H.. Photosynthetic acclimation, biomass allocation, and water use efficiency of garlic in response to carbon dioxide enrichment and nitrogen fertilization. *Journal of the American Society for Horticultural Science*, 2016:141(4), 373-380.

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