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

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Authors' contributions

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

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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 R*abi* 2020-21 and 2021-22. The experiment comprising total 32 treatment combinations; eight sources of

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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 tha^{-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. 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.

1. 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 [1]. 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 [2]. Plant nutrients plays an important role in crop production and used various source of nutrients, they supplied 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 [3].

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 [4,5] for a number of different species typical of grain and fruit production. The temperature response of different species has been evaluated by [6-10]. 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 [11]. 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 [12]. Current projections are or concentrations to continue to rise to as much as 500–1000 ppm by the year 2100 [13]. While a great deal of media and public attention has focused on the effects that such higher concentrations of CO_2 are likely to have on global climate, rising CO_2 concentrations are also likely to have profound direct effects on the growth, physiology, and chemistry of plants, independent of any effects on climate [14]. 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 [15]. 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.

2. MATERIALS AND METHODS

2.1 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^{o}C while in the winters it may fall as low as 0^{o}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^{0}C to 35.1^{0}C and 2.7^{0}C to 17.9^{0}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^{0}C to 41.4^{0}C and 3.1^{0}C to 19.1^{0}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.

2.2 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 tha^{-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 P_2O_5 and 100 kg K_2O was applied.

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, CO_2/H_2O 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/m^{-2}/s) to transpiration rate (mmol/m^{-2}/s). Carboxylation efficiency is the ratio of net photosynthesis rate (umol/m^{-2}/s) to Internal CO_2 concentration (ppm)

Table 1. Details of the experiment as follows

Season	**Rabi, 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

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

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_2O in	H_2O out	RH in	RH out	VPD	E	PAR	Pn	C	int_CO_2	WUE	Ce
M_0F_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_0F_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_0F_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_0F_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_1F_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_1F_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_1F_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_1F_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_2F_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_2F_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_2F_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_2F_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_3F_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_3F_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_3F_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_3F_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_4F_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_4F_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_4F_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_4F_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_5F_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_5F_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_5F_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_5F_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_6F_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_6F_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_6F_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_6F_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_7F_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_7F_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_7F_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_7F_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

3. RESULTS 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 CO_2, vapor pressure Deficit, outlet CO_2 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 P_2O_5 and 100 kg K_2O *i.e.,* 100% recommended dose of fertilizer (M_3F_3). It might due to photosynthesis is the formation of carbohydrates from CO_2 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 CO_2 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 [16-18] 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 [19-24].

4. 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 (M_3F_3) can be recommended for garlic growers to achieve the better performance under the hyper arid Region of Rajasthan.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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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	

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