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Performance of Summer Greengram (*Vigna radiate* L.) under Various Orientations in Semi-arid Region, Haryana (India)

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ABSTRACT

Background: Summer green gram (*Vigna radiata* L.) commonly known as "moong" belongs to the Fabaceae family that currently is grown in different parts of the world and it has a significant role in nutrition in developing countries. It is a short-duration crop grown over a wide range of environments in India. Light interception and penetration as well as albedo are affected by row orientation.

Methods: Line Quantum sensor (Model L1-191R) was used to measure PAR (400 nm-700 nm) at important phenophases at different orientations. In order to better understand how plants absorb light in different row orientations, such as North-South (NS), East-West (EW) and North-West-Southeast (NW-SE), a study was carried out at the Chaudhary Charan Singh Research Farm of Agricultural Meteorology at the Haryana Agricultural University in Hisar India during *summer* 2020 and 2021. Heat and radiation use efficiency measure at flowering, pod and physiological maturity by using weather data and other indices.

Result: It was found that moong variety MH 421's pod initiation stage was when PAR absorption was greatest, along with other factors including NW-SE orientation. Row orientation heat use efficiency ranges between (2.6 to 7.6 kg ha^{-1} °C day^{-1}) and in variety (1.4 to 2.7 g MJ^{-1}) and radiation use efficiency ranges between (1.4 to 2.8 g MJ^{-1}) and in row orientation (1.4 to 2.7 g MJ^{-1}) (2.7 to 7.7 kg ha^{-1} °C day^{-1}). As a consequence, it was determined that diagonal row orientations generated better yield and yield attributes because PAR absorption was higher in such orientations. In dry and semi-arid areas, it can be used to produce food and forage.

Key words: HUE, PAR, Row orientations, RUE, Summer greengram.

INTRODUCTION

Summer greengram (*Vigna radiata* L.) commonly known as "moong" belongs to the Fabaceae family that currently is grown in different parts of the world and it has significant role in nutrition in developing countries. It is a short-duration crop grown over a wide range of environments in India. Pulses are grown in India in an area of 29.99 million hectares with an annual production of 25.23 million tons in the year 2018-19 and the productivity of pulses was 841 kg/ha (DES, 2019). In India, the area under greengram was 40.70 lakh hectares with production and productivity was 19.01 lakh tons and 467 kg ha^{-1} respectively during the period 2017-18 (Anonymous, 2018). In Haryana, the average area under greengram during the year 2017-18 was 13.6 hectares with productivity of 9.4 tonnes per hectare (Haryana Statistical Abstract, 2017-18). In Haryana, greengram is mostly grown in the western agroclimatic zone having semi-arid type of climatic conditions.

In Haryana, it is impossible to increase financial returns by expanding cropped area as there is little scope left for further expansion of the cultivable area.

Light interception penetration and albedo are affected by row orientation. Singh *et al*. (2020) showed that all the growth parameters, yield attributes and yield were significantly higher in the North-South sowing direction as compared to East-West. Net radiation is an essential key to assessing evapotranspiration and precise estimation for water resource management on a regional scale (Villa Nova *et al*., 2006; Ryu *et al*., 2008; Pereira *et al*., 2011). PAR absorption by canopy results in increased plants biomass and grain weight (Kooman and Haverkort, 1995; Shaykewich *et al*., 1998).

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The objectives of the study are to investigate the performance of summer greengram in various row orientations and identify the useful orientation and variety for the highest yield production.

MATERIALS AND METHODS

Site description

The field experiment was conducted during 2020 and 2021 at the Research Farm of Agromet (latitude 29°10′N, longitude 75°46′E and altitude of 215.2 m) Chaudhary

Charan Singh Haryana Agricultural University, Hisar (Haryana), India, which is located in western agroclimatic zone. The prevailed weather condition was shown in Fig 1.

Experiment design and field management

During the crop seasons of 2020 and 2021, a factorial randomised block design with nine treatments was employed. Both the years, the experiment was carried out near the agromet observatory. Each of the three complete replications has three 6 m × 6 m plots with nine treatments each. The space between each row and plant was 30 cm × 10 cm. Before seeding, a soil sample from the experiment field was randomly taken at various depths between 0 and 15 and 15 and 30 cm, to examine the physico-chemical characteristics of the soil.

Measurements and calculations

Photosynthetic active radiation

Line quantum sensor (Model L1-191R) was used to measure PAR (400 nm-700 nm) at important phenophases *i.e.* flower initiation, pod initiation and physiological maturity at 12:00 hr at top, middle and bottom of canopy due to minimize the shadow effect. To measure reflected radiation, sensor was kept inverted above the crop canopy at 1m height. To take transmitted radiation, the line quantum sensor was kept on ground across the rows diagonally. IPAR was obtained by keeping the sensor above the canopy. Absorbed radiation was calculated by using the following formula:

Absorbed radiation (A) = IPAR - Reflected radiation by the canopy - Transmitted radiation

Whereas:

IPAR: Incidence radiation on the canopy (MJ/m^2)

Light interception (%) was calculated as:

$$\text{Interception (\%)} = \frac{\text{Intercepted PAR}}{\text{Incident PAR at the top of canopy}} \times 100$$

Heat use efficiency (HUE)

Thermal use efficiency is calculated by ratio of biomass yield in g/m^2 to the accumulated heat units *i.e.* growing degree days (GDD).

$$\text{HUE (g/m}^2\text{/°C day)} = \frac{\text{DM (g/m}^2\text{) accumulated}}{\text{Accumulated heat units (°C days)}}$$

Where,

DM = Dry matter.

Radiation use efficiency (RUE)

Radiation use efficiency is computed by the ratio of biomass yield in g/m^2 to the accumulated divided by IPAR.

$$\text{RUE (g/MJ)} = \frac{\text{Biomass (g/m}^2\text{) accumulated}}{\text{APAR (MJ/m}^2\text{) accumulated}}$$

Yield and yield attributes

Number of pods per plant

Five plants were taken from each plot and number of pods per plant was derived.

Pod length

Five plants were taken from each plot and pod length with aid of scale measuring and expressed as cm.

Test weight (g)

One-thousand grains randomly were counted from each plot after threshing and weighing the grains with electronic balance.

Grain yield (kg ha^{-1})

Grains were separated manually and biological yield was obtained afterward from each plot. The derived yield per plot was converted into kg/ha.

Biological yield (kg/ha)

After harvesting the summer greengram crop, it was sun dried for a week to record of biological yield. With the help of balance weight machine of net harvested area of summer greengram in kg ha^{-1} was computed.

Harvest index (HI %)

The harvest index is a ratio of total grain yield by the total biological yield (grain + straw yield) and multiplied by 100.

Statistical analysis

Data collected during the study were statistically analyzed by using the technique of analysis of variance (ANOVA) as applicable to Split plot design (Gomez and Gomez, 1984) to achieve target of study. The significance of the treatment effects were determined using F test at 5% probability. To

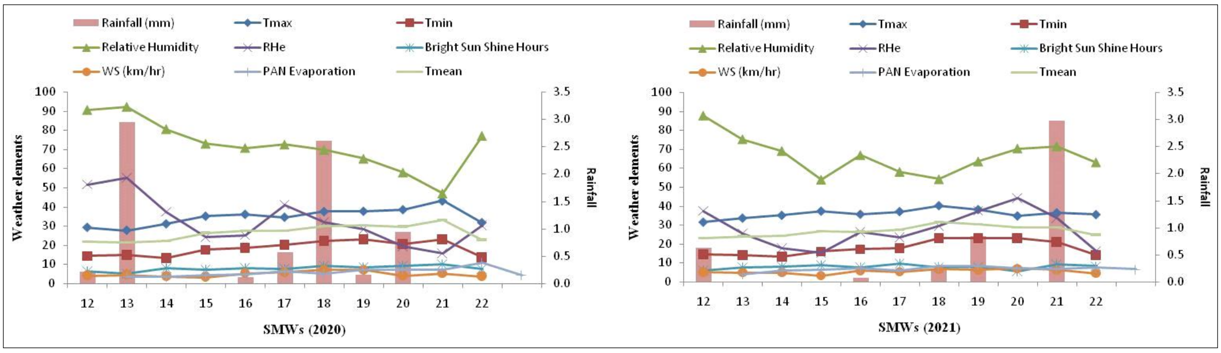

Fig 1: Mean weekly meteorological data during crop season of 2020 and 2021.

judge the significant difference between means of two treatments, the critical difference (C.D.) was worked out using following formula:

$$CD = \sqrt{\frac{2 \times EMS}{n}} \times \text{t value at 5\%}$$

Where,
CD = Critical difference.
EMS = Error mean sum of square.
n = Number of observations.
t = Value of t-distribution at 5% level of error degree of freedom.

RESULTS AND DISCUSSION

Heat and radiation use efficiency

Heat use efficiency of plant increase with increase the plant growth and development as represented in Table 1. Heat use efficiency was observed maximum at physiological maturity in variety MH 421 (6.8 kg ha^{-1} °C day^{-1} (2020) and 7.7 kg ha^{-1} °C day^{-1} (2021) and in row orientation NW-SE (7.3 kg ha^{-1} °C day^{-1} (2020) and 7.8 kg ha^{-1} °C day^{-1} (2021) due to maximum plant height and growth as shown in Table 1. Radiation use efficiency was observed maximum at physiological maturity in variety MH 421 (2.7 g MJ^{-1} (2020) and 2.8 g MJ^{-1} (2021) as well as in row orientation NW-SE (2.8 g MJ^{-1} (2020) and 2.8 g MJ^{-1} (2021) due to maximum plant height and accumulated dry matters as shown in Table 1. Among varieties, MH 421 was observed maximum heat and radiation use efficiency followed by MH 1-25, MH 318 as well as among orientation, NW-SE was observed maximum followed by NS, EW. Similar result was found by (Yousefi *et al*. 2020; Kukal *et al.,* 2020).

Photosynthetic active radiation

Photosynthetic active radiation absorption was found that increases with increase the number of leaves and chlorophyll content at flower to pod stage after that decline at physiological maturity due to decrease the chlorophyll content as shown in Table 2. It was found that maximum absorption of light at pod initiation in varieties (81.9% (2020) and 82.8% (2021) as well as in row orientations (81.4% (2020) and 84.0% (2021). Among varieties, MH 421 was observed maximum PAR followed by MH 1-25, MH 318 as well as among orientation, NW-SE was observed maximum followed by NS, EW during both the crop season due to maximum LAI, maximum chlorophyll content. Similar result found by Basu *et al.* (2020).

Yield and yield attributes performance at various row orientations

Yield of any crop species depends upon the source-sink relationship and is the cumulative function of various growth parameters and yield attribute characters *viz*., no. of pod per plant, pod length per plant, seed weight or 1000-grain weight (g), seed yield (kg/ha), straw yield (kg/ha), biological yield (kg/ha) and harvest index (%) as shown in Table 3. The dry matter partitioning during flowering to pod stage of

Table 1: Heat and radiation use efficiency at different phenophases of moong varieties sown under various orientations during 2020 and 2021.

Treatment	Heat use efficiency (kg ha^{-1} °C day^{-1})						Radiation use efficiency (g MJ^{-1})					
	2020			2021			2020			2021		
	F.I	P.I	P.M	F.I	P.I	P.M	F.I	P.I	P.M	F.I	P.I	P.M
Varieties												
MH 421	3.1	6.6	6.8	3.8	6.7	7.7	1.7	2.6	2.7	1.9	2.6	2.8
MH 318	2.7	6.0	6.3	3.3	6.2	6.8	1.4	2.4	2.5	1.7	2.4	2.5
MH 1-25	2.7	6.4	6.4	3.3	6.3	7.6	1.5	2.5	2.6	1.7	2.4	2.7
SE (m) ±	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.0	0.0	0.1	0.1	0.1
CD @ 5%	0.3	0.3	0.4	0.5	NS	0.5	0.2	0.1	0.1	0.2	NS	0.2
Row orientation												
North-South	2.9	6.1	6.3	3.8	6.1	7.1	1.5	2.4	2.6	1.9	2.3	2.6
East-West	2.6	6.0	6.0	3.0	6.0	7.1	1.4	2.4	2.4	1.5	2.3	2.6
NW-SE	3.1	6.9	7.3	3.6	7.2	7.8	1.7	2.7	2.8	1.8	2.7	2.8
SE (m) ±	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.0	0.0	0.1	0.1	0.1
CD @ 5%	0.3	0.3	0.4	0.5	0.8	0.5	0.2	0.1	0.1	0.2	0.3	0.2

*F.I- Flower initiation, P.I- Pod initiation, P.M- Physiological maturity.

Table 2: Photosynthetic active radiation (%) in moong varieties sown under various orientations during crop season 2020 and 2021.

Treatment	Flower initiation						Pod initiation						Physiological maturity					
	2020			2021			2020			2021			2020			2021		
	T (%)	R (%)	A (%)	T (%)	R (%)	A (%)	T (%)	R (%)	A (%)	T (%)	R (%)	A (%)	T (%)	R (%)	A (%)	T (%)	R (%)	A (%)
Varieties																		
MH 421	21.2	6.1	72.7	19.1	7.0	73.9	10.7	7.4	81.9	10.8	6.4	82.8	35.9	17.6	46.6	29.0	18.4	52.5
MH 318	23.8	5.7	70.5	21.6	6.4	72.1	12.5	6.6	80.8	11.6	6.7	81.7	36.2	17.5	46.3	31.2	17.1	51.7
MH 1-25	21.6	5.8	72.6	20.5	6.5	73.0	11.8	7.1	81.1	12.9	6.4	80.7	36.0	17.6	46.4	30.2	17.8	52.0
SE (m) ±	0.4	0.1	0.4	0.3	0.1	0.3	0.2	0.1	0.2	0.5	0.1	0.5	0.6	0.6	0.6	0.3	0.2	0.3
CD @ 5%	1.1	0.4	1.1	0.9	0.4	0.9	0.7	0.3	0.7	1.5	0.4	1.6	NS	1.9	1.8	0.9	0.7	NS
Row orientation																		
North-South	22.8	5.8	71.3	20.3	6.5	73.2	11.7	7.0	81.3	12.4	6.7	80.9	36.2	17.1	46.7	29.6	17.7	52.6
East-West	24.0	5.6	70.4	21.4	6.4	72.2	12.5	6.8	80.7	13.0	6.6	80.3	36.5	17.5	46.0	31.7	17.3	51.0
NW-SE	20.8	6.1	73.1	19.5	6.9	73.6	10.9	7.3	81.8	9.8	6.2	84.0	34.3	17.1	48.6	29.0	18.3	52.6
SE (m) ±	0.4	0.1	0.4	0.3	0.1	0.3	0.2	0.1	0.2	0.5	0.1	0.5	0.6	0.6	0.6	0.3	0.2	0.3
CD @ 5%	1.1	0.4	1.1	0.9	0.4	0.9	0.7	0.3	0.7	1.5	0.4	1.6	1.8	1.9	1.8	0.9	0.7	0.9

T- Transmission, R- Reflection, A- Absorption.

Table 3: Yield and yield attributes of moong varieties sown under various orientations during crop season 2020 and 2021.

Treatment	2020							2021						
	No of pods/ plant	Pod length	1000-seed weight	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index	No of pods/ plant	Pod length	1000-seed weight	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index
Varieties														
MH 421	20.44	7.57	42.56	860.89	1887.2	2748.14	0.31	22.64	7.73	43.00	943.72	2029.9	2973.64	0.32
MH 318	15.11	6.88	42.00	758.28	1746.5	2504.79	0.30	20.76	6.34	41.22	843.32	1840.9	2684.27	0.31
MH 1-25	18.00	6.84	41.33	839.08	1856.8	2695.87	0.31	21.09	7.07	41.11	899.06	2090.1	2989.18	0.30
SE (m) ±	0.68	0.2	1.02	25.69	30.15	43.90	0.01	1.28	0.17	0.55	23.43	33.95	53.31	0.00
CD @ 5%	2.06	0.61	NS	77.68	91.17	132.75	NS	NS	0.52	1.66	70.85	102.65	161.18	0.01
Row orientation														
North-South	17.56	7.02	39.78	776.53	1813.9	2590.52	0.30	19.20	6.98	41.22	855.32	1913.9	2769.31	0.31
East-West	16.33	6.76	39.67	769.12	1781.5	2550.60	0.30	20.96	6.92	39.11	862.65	1966.3	2829.03	0.30
NW-SE	19.67	7.52	46.44	912.61	1895.1	2807.67	0.32	24.33	7.24	45.00	968.13	2080.6	3048.75	0.32
SE (m) ±	0.68	0.2	1.02	25.69	30.15	43.90	0.01	1.28	0.17	0.55	23.43	33.95	53.31	0.00
CD @ 5%	2.06	0.61	3.09	77.68	91.17	132.75	0.02	3.87	NS	1.66	70.85	102.65	161.18	NS

plants parts is affected by the environmental change or due to high minimum temperature, increase the respiration rate during 2020 crop season. Yield and yield attributes performance were significantly high in MH 421 variety and NW-SE direction in 2021 crop season due to favorable weather condition at physiological maturity. Among different varieties and row directions, no. of pod per plant, pod length per plant, 1000 seed weight, seed yield (kg/ha), straw yield (kg/ha), biological yield (kg/ha) and harvest index (%) were found higher in MH 421 variety and NW-SE direction during both the crop season due to high leaf area index, no. of branches and accumulated high dry matter, maximum absorption of light. However, the highest seed yield (943.73 kg/ha), biological yield (29.73.64) in MH 421 varieties and row direction (968.13 kg/ha), biological yield (3049.75 kg/ha) in NW-SE during the 2021 crop season as shown in Table 3. The yield reduction under late sowing dates have been similar results were also reported earlier by also (Fraz *et al*., 2006; Miah *et al*., 2009; Jahan and Adam, 2012 and Kumar *et al*., 2013).

CONCLUCION

The results showed that diagonal orientation of summer greengram varieties improved yield as compare to other. IPAR of summer greengram was observed high in 30×10 cm spacing under diagonal orientation. Row orientation regulated IPAR by leaf inclination and plant height and changing the photosynthetic capacity and subsequently enhancing RUE of the crop, which ultimately improved yield and its attributes. The NW-SE orientation was greater than one in all the other treatments. In variety MH 421 and orientation NW-SE, the higher photosynthetic capacity was found in summer moong than others varieties and orientations. Overall, MH 421 and NW-SE displayed greater RUE and IPAR, resulting in greatest yield among row orientations, was optimum row orientation for summer moong in regions similar to this study site. Therefore, summer greengram was sown in diagonal orientation (North West-South East) could be efficient approach for sustainable forage and yield production in semi-arid regions in Haryana. Future research may optimize row orientation effects to further improve the yield and its attributes. A deeper understanding of row orientation effects on canopy structure and RUE is needed.

Conflict of interest

There is no conflict of interest among authors.

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