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Impact of micro-meteorological parameters on growth and productivity of mung bean under different agro-forestry systems in arid Rajasthan

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ABSTRACT

Micro-weather investigations (air temperature, relative humidity profiles, thermal time, energy balance and light interception) were carried out in rainfed mung bean (*Vigna radiata* cv. S8) sown as sole crop as well as intercrop with *Ber (Zizyphus mauritiana)*, *Khejri* (Prosopis cineraria) and Babul (*Acacia nilotica*) during three *Kharif* seasons (1996-99) in Jodhpur. Micro-climatic modifications by the different agro-forestry systems during various crop growth stages are compared with open field. Air temperature inside the agrihorticulture system (*ber* + mung bean) and sole crop were lower by 1.6 to 2.8 °C and 1.4 to 2.6 °C, respectively, than the open field. Grain yield of mung bean intercrop with ber was 5 to 20% higher in comparison to sole crop depending upon rainfall and drought conditions in the arid region.

Key words: Micro-climatic modification, Drought, Mungbean, Intercrops, ber,

Micrometeorological studies in natural rain forest have been carried out in the past (Leopoldo *et al.*, 1984; Shuttleworth *et al.*, 1984, 1985). Agroforestry has a capacity for the beneficial modification of microclimates (Huxley, 1983; Brunig & Sander, 1983). Microclimatic studies in shelter-belt plantings had been carried out in the past (Rao *et al.*, 1983) and also in conventional intercropping systems (Marshall & Willey, 1983). Limitations in the study of microclimate often rest not in the collection of data but in the choice of appropriate forms of analysis (Monteith *et al.*, 1981) and it is important not only to quantify changes in microclimate but also to relate them to plant responses.

Information on micrometeorological aspects specifically for agroforestry system in India is almost non-existent for arid zone. The bioclimatic requirements and phenological behaviour of the species that have been adopted in agroforestry systems are largely unknown since most of these species are of recent introduction. Microclimatic studies for arid fruit orchard and agroforestry systems have only recently begun (Singh *et al.*, 1998, 1999). However, much of the agrometeorological information and database, if properly developed and recorded, can be useful for listing and selection of sustainable agroforestry system for the regions. In this paper an attempt has been made to compare microclimate of sole and intercropping systems.

MATERIALS AND METHODS

Field experiments on mung bean (*Vigna radiata* cv. S8) were conducted for three consecutive *kharif* seasons (July to September) in 1996, 1997 and 1999 at the Central Arid Zone Research Institute, Jodhpur (26.3°N, 73.02°E).

Three treatments of rainfed mung bean sown as sole crop as well as intercrop with *Ber* (*Zizyphus mauritiana*), *Khejri* (*Prosopis cineraria*) / *Babul* (*Acacia nilotica*) were maintained to conduct the experiment. The long term (1963-2000) mean annual rainfall of Jodhpur is 389.3 mm, with the major part about 85 to 90% received during southwest monsoon (*kharif*) season between end of June and September. May is the hottest month with mean maximum temperature of 41.0°C and January is the coldest month with mean minimum temperature of 10.2°C. However, these temperatures ranged from 34.2 to 36.1°C and 23.7 to 26.7°C during the cropping season. Mean relative humidity (RH) varied between 40 and 82%, wind speed from 6.6 to 12.0 km h^{-1} and sunshine hours varied between 6.7 and 9.1 hours day-1 during the cropping season. These normal climatic conditions cause high mean evaporation rates from 4.5 mm day^{-1} in December to 14.8 mm day^{-1} in the hottest month of May. They also varied between 6.8 and 9.1 mm day^{-1} during July to September.

The soils in the experimental area developed from rhyolite and modified by alluvial and aeolian activities belong to the family of coarse loamy, mixed, hyperthermic of Camborthids. The surface layer is fine loamy sand in texture with 6.55% clay and 0.52% silt and subsoil is non-calcareous sandy loam, low in organic carbon (0.16%). Soil analysis showed the available P (Olsen's method) and K (ammonium acetate method) contents to be 17 and 180 kg ha^{-1}, respectively. The moisture contents at field capacity and at -15 bar tension were equivalent to 9.5 and 3.0% (w/w), respectively.

Jujube (cv. Gola) was planted ten years ago separately in rows at a spacing of 6x6 m. Similarly, near to the jujube orchard, khejri and babul were also planted separately at the same time and fashion. Inter row spacing of these plantations was used to grow mung bean as intercrop. The inter-and intra-row spacing for mung bean crop were maintained at 40 cm and 10 cm, respectively, both in sole as well as in intercrop. Micro-meteorological observations were recorded at periodical interval three times (09:00, 12:00 and 15:00 hour) in a day from July to September in all the treatments. The net radiation, albedo, soil heat flux, radiation profile, humidity and air temperature were measured. Air temperatures and humidity profiles were recorded using an Assman Psychrometer. The net radiation and soil heat flux were obtained using a Funk Type radiometer and heat plates, respectively. Tube solarimeter was used for measurement of radiation interception by the canopy.

Besides these, daily maximum and minimum temperatures observed in an agrometeorological observatory near the experimental site were also collected. A minimum temperature (threshold) of 8°C was taken as base temperature for arid *kharif* legume crop (Singh *et al.*, 2000) to work out the thermal time requirements for completion of different growth stages. At the beginning of each growing season, 10 representative plants were marked in each treatment plot (5x2 m) to collect the detailed phenological and growth data. Leaf tip appearance data on the main shoot (MS) and on the primary branch (PB) were collected every alternate day. Ramana Rao *et al.* (1981) and Sastri *et al.* (1982) classified the agricultural droughts based on moisture adequacy index; and AET/PET ratio during different stages of crop growth have been used to classify the intensity of the agricultural drought in this study. The potential evapotranspiration (PET) values were computed using modified Penman's equation. The actual evapotranspiration (AET) values were arrived at from the water balance computations using the book keeping procedure of Thornthwaite & Mather (1955). Micro-climatic modification inside mung bean canopy intercrop with different trees is quantified with the distribution of temperature, humidity and radiation inside the crop canopy.

RESULTS AND DISCUSSIONS

Air temperature and relative humidity (RH) profiles

Air temperature profiles measured inside the crop canopies (Table 1) revealed that at 25 cm height it was less by 1.4 to 2.6 °C and 1.6 to 2.8 °C in the sole and intercrop field, respectively, in comparison to bare field (34.4 °C) at the same height during the maximum temperature epoch (afternoon, 15:00 hour). Above the crop canopy (150 cm height) the temperature at this height was 32.0°C in both the cropped plots in comparison to bare field (33.2°C).

Relative humidity (RH) measurements up to 150 cm height inside and out side the crop canopy (Table 1) at 45 DAE indicated that during afternoon (15:00 hour) it was the highest (68%) inside the intercrop with jujube followed by sole mung bean (57%) and the lowest (48%) over the open bare field. Similarly, RH at 9:00 hour were 77% and 74% inside the intercrop with jujube and sole mung bean system, respectively, against 71% over the bare field. Relative humidity inside the intercrop with jujube was high by 9 to 20% during afternoon period (15:00 hour) and by 1 to 5% only during forenoon (9:00 hour) period against the bare soil value near the experiment. This increase in RH was mainly contributed by transpired water vapour through leaves of jujube tree, trapped inside the canopy, depending upon wind velocity and turbulence motion.

Crop phenology and thermal time

Response of crop developmental processes to temperature, is generally expressed using the concept of thermal time or accumulated temperature (Singh *et al.*, 2000 for moth bean; Singh *et al.*, 1999 for jujube orchard). In general, under arid condition mung bean crop took thermal time of 838 to 860°Cd to reach flowering and 1471 to 1556 °Cd for physiological maturity irrespective of sole or intercrop.

Leaf tip appearance in mung bean in relation to thermal time

Leaf tip appearance in the three treatments of mung bean (cv. S8) grown as sole, intercrop with *ber* and *khejri* in relation to cumulative thermal time (°Cd) from day after emergence (DAE) was worked out. The regression equation fitted between main shoot (MS) leaf appearance (Y) and thermal time (X) under the above three treatments, respectively, were:

$$Y_1 = -0.0089 + 0.0122X; \; R^2 = 0.995 \quad ---(1)$$

$$Y_2 = -0.2763 + 0.0135X; \; R^2 = 0.997 \quad ---(2)$$

$$Y_3 = 0.1041 + 0.0115X; \; R^2 = 0.999 \quad ---(3)$$

In all the treatments relationships are significantly linear. On an average, thermal time required for each leaf production on main shoot was 74 to 87 °Cd. However, leaf appearance was faster (0.0135 leaves per °C day) in case of intercrop with ber and slower (0.0115 leaves per °C day) in case of intercrop with *khejri*, in comparison with sole crop (0.0122 leaves per °C day).

Table 1 : Air temperature (°C) and relative humidity (%) profiles inside and outside the mung bean crop canopies at 45 DAE on September 4, 1996 under different arid zone farming systems.

(A) Air temperature (°C) profiles

Heights (cm)	Open field		Sole mung bean		Mung bean with *ber*	
	9:00 hrs	15:00 hrs	9:00 hrs	15:00 hrs	9:00 hrs	15:00 hrs
5	29.8	35.4	28.4	32.8	28.2	32.6
25	29.4	34.4	28.2	32.4	28.2	32.4
50	29.0	33.8	28.2	32.4	28.2	32.2
150	28.8	33.2	28.0	32.0	28.2	32.0

(B) Relative humidity (%) profiles

Heights (cm)	Open field		Sole mung bean		Mung bean with *ber*	
	9:00 hrs	15:00 hrs	9:00 hrs	15:00 hrs	9:00 hrs	15:00 hrs
5	72	48	73	54	77	68
25	72	51	72	57	77	68
50	72	53	74	56	75	67
150	71	53	72	57	72	62

Table 2 : Energy balance over mung bean during peak day hour (12:00 Noon) at 45 DAE on 4th September 1996.

Treatments	Incident radiation, R_s (Wm^{-2})	Net radiation, R_n (Wm^{-2})	Soil heat flux, G (Wm^{-2})	R_n - G (Wm^{-2})
Bare soil (open field)	858	466	139	327
Sole mung bean	858	480	47	433
Mung bean with ber	858	551	66	485

Branch appearance

The appearance of the first primary branch on the main shoot of plants required a mean thermal time of 462 to 538 °Cd after emergence under the different treatments. The first branch was estimated to have appeared when there were five to seven leaves on the main shoot. Two primary branches were common on each plant.

Energy balance over the crop canopy

Net radiation (Wm^{-2}) was the highest (551) over mung bean intercrop with ber followed by

Table 3: Growth and yield of mung bean under different cropping systems during various rainfall situations at 60 days after emergence (DAE).

Year	Rainfall (mm)	Rainy-days	Treatments	Plant height (cm)	Leaf area index (LAI)	Light intercep -tion (%)	Yield (kg ha^{-1})
1996	328.8	12	Sole mung bean	44.3	0.51	70	864
			Mung bean with *ber*	58.0	0.71	74	960 (11)
1997	221.1	12	Sole mung bean	33.2	0.47	55	640
			Mung bean with *ber*	40.9	0.63	60	770 (20)
			Mung bean with *khejri*	42.2	0.49	48	560
1999	155.8	07	Sole mung bean	29.9	0.29	39	310
			Mung bean with *ber*	31.3	0.31	45	325 (05)
			Mung bean with *babul*	Crop	Dried	--	No yield

Note: Figures in parenthesis indicate per cent increase in mung bean yield intercrop with ber over the sole crop during the year.

sole crop (480) and open field (466) against incident solar radiation of 858 Wm^{-2} (Table 2). Contrary to this, open field exhibited higher (139 Wm^{-2}) soil heat flux compared to sole crop (66 Wm^{-2}) and intercrop (47 Wm^{-2}). However, energy availability (R_n - G) was higher over intercrop than sole crop for utilization by the crop in evapotranspiration and sensible heat.

Crop growth in relation to rainfall and radiation interception

During cropping season of 1996, total seasonal (July-Sept) rainfall of 328.8 mm had occurred and was distributed over 12 rainy days (Table 3) and seems to have resulted better growth and productivity under all the treatments in comparison to the years 1997 and 1999. In contrast, the total seasonal precipitation during the same period in 1999 was 155.8 mm, distributed over only 7 rainy days. Such a low rainfall, during the season, was not enough to support the crop growth and ultimately crop suffered with moderate drought during its reproductive stage. Radiation profile measurements inside the crop canopy revealed that 70 to 74% of radiation was intercepted by the canopy before it reached the soil surface during the *kharif* season of 1996. The maximum radiation interception was observed to coincide with the period of maximum leaf area index (LAI) of the crop in all the years. Under moisture stress conditions of 1999 a decrease in the radiation interception by the crop was of the order of 29 to 31% due to sharp decrease in LAI (Table 3). Maximum crop height up to 58.0 cm

Table 4: Actual evapotranspiration (AET) and drought intensity during different growth stages of mung bean at CR farm, Jodhpur.

Year	Parameters	Seedling Stage (S)	Vegetative Stage (V)	Reproductive Stage (R)	Crop cycle	Grain yield (kg ha^{-1})	WUE (kg ha^{-1} mm^{-1})
1996	AET (mm)	73	98	83	283	864 SC	3.05 SC
	AET/PET	1.0	0.97	0.77	0.84		
	Drought Intensity	No drought	No drought	No drought	No drought	960 IC	3.39 IC
1997	AET (mm)	50	80	65	227	640 (26) SC	2.82 SC
	AET/PET	0.74	0.76	0.61	0.65		
	Drought Intensity	Mild drought	Mild drought	Mild drought	Mild drought	770 (20) IC	339 IC
1999	AET (mm)	45	60	35	155	310 (64) SC	2.00 SC
	AET/PET	0.62	0.60	0.33	0.44		
	Drought Intensity	Mild drought	Mild drought	Moderate drought	Moderate drought	325 (66) IC	2.10 IC

Note: SC = sole crop and IC = intercrop with *ber.*
Figures in parenthesis indicate per cent reduction in yield with respect to good rainfall year 1996.

was recorded in the intercrop with jujube during good rainfall year 1996 and minimum up to 29.9 cm in sole crop treatment during drought year 1999. The mung bean crop growth remained higher in the intercrop with ber compared to sole and other treatments in all the years with different rainfall situations. Consequently, crop yields recorded were higher by 5 to 20% from intercrop with *ber,* over sole crop yield. The highest crop yield (960 kg ha^{-1}) was obtained from intercrop with *ber* in the good rainfall year of 1996 and the lowest (310 kg ha^{-1}) from sole crop during drought year of 1999.

Agricultural drought and crop productivity

Severity of drought experienced by mung bean crop at different growth stages during three crop growing seasons (Table 4) revealed that the crop did not experience severe drought at any stage of crop growth during the year 1996. However, during 1997, the crop experienced droughts of mild nature during seedling and reproductive stages, which reduced yield by 20 to 26% over the good rainfall year. During *kharif* 1999, crop suffered mild drought during seedling and vegetative stages and moderate drought during reproductive stage, which had much adverse effect on crop production as observed by 64 to 66% reduction in yield during the year. Actual evapotranspiration (water use) during the three years of experiments were 283, 227 and 155 mm during good year (1996), normal year (1997) and poor year (1999), respectively. Water use efficiency (WUE) ranged between 2.00 and 3.39 kg $ha^{-1}mm^{-1}$ during the three years. Relatively lower values of WUE correspond to sole crop as well as the cropping season with poor rainfall.

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