ON SOME AGROMETEOROLOGICAL ASPECTS OF MOONG-BEAN (*VIGNA RADIATA*) IN INDIA

1. Moong-bean popularly known as green gram (*Vigna radiata* L), is one of the important pulses in India. It is cultivated all over the country; the major producing states being Uttar Pradesh, Madhya Pradesh, Punjab, Andhra Pradesh, Rajasthan, Karnataka and Tamil Nadu. Unfortunately, not much work seems to have been done on moong-bean as compared to other pulses. The crop is grown mostly in kharif over central peninsular India, while it is also grown as a summer crop. In summer, the crop needs irrigation for higher production. According to Mandal *et al*. (1990) monocrop moong-bean produces higher yield (nearly 100 kg/ha) than when intercropped. The crop is photoinsensitive and heat tolerant. Being a deep rooted leguminous crop, it requires less water throughout life of the crop, it can conserve moisture because of its good canopy cover. The crop can grow well in moderate temperature, the ideal range of temperature is 20 to 35° C. The crop used to be grown under rainfed situation with profile stored soil moisture. Heavy rain at flowering is harmful, even moist wind at this stage interfere with fertilization. Being a *summer* crop at Raipur, the pre-monsoon shower is useful for this crop. It can be grown in marginal and sub-marginal lands with low to medium fertility status. The pulse does best on deep, well-drained loamy soil in the alluvial tract in the north as well as on the red and black soils of peninsular and southern India. It is also cultivated on light or shallow stony soils to clayey soils.

In view of its importance as food item and also as it is not been much studied agroclimatically, an attempt has been made in paper to discuss some of the agro meteorological aspects of the crop.

2. The study utilises the data on moong-bean cultivated as a part of evapotranspiration (ET) experiment at different locations, where IMD has gravimetric lysimeters as part of ET network. The crop normally takes 75 to 105 days to complete its growth cycles. Naturally,

TABLE 1

Phase wise water used by the moong-bean (mm)

Station	Stages			Short duration				Stages			Long duration			
	A	B	C	Variety	Date of sowing	Duration days	Yield (kg/ha)	A	B	C	Variety	Date of sowing	Duration days	Yield (kg/ha)
							Kharif							
Rahuri	39.2 (15.2)	143.5 (55.5)	75.6 (29.3)	PM 2	28 Jun 1989	77	990.0	64.4 (25.8)	121.8 (48.7)	63.7 (25.5)	PM-2	25 Jun 1991	86	970.0
Durgapura								84.7 (32.3)	91.7 (34.3)	86.1 (32.8)	RMG - 325	9 Jul 1993	90	840.5
								97.3 (31.4)	123.7 (39.7)	89.6 (28.9)	RMG- 268	9 Jul 1994	88	1257.5
Dantiwada	58.4 (19.8)	170.1 (57.8)	65.8 (22.3)	K-851	14 Jul 1992 5 Jul 1993	64 70	1346.15							
							Summer							
Raipur	32.9 (5.9)	290.5 (52.5)	230.3 (41.6)	Baisakhi Special	14 Apr 1980	70	976.5	42.0 (7.6)	206.6 (37.7)	299.9 (54.7)	Pusa Baisakhi	31 Mar 1981	91	1944.0
												20 Mar 1982	102	1946.5
												1 Apr 1983	91	2208.0

Note : Figures within the parenthesis represents percentage to the total water need.
Raipur - Average water used in three years. Dantiwada - Average water used in two years.
A - Germination to boot leaf, B - Boot leaf to pod formation, C - Pod formation to maturity.

the water requirement and other characteristics of this crop will vary widely. Water requirement of the crop would also be different when grown in different seasons. Though in some parts moong-bean is also grown in rabi season, in the present study at none of the stations it was raised as a rabi crop. In view of this, the crop have been grouped in two categories *viz.* kharif and summer and also depending on the duration, as short (64 to 77 days) and long duration *i.e.* more than 77 days. The present study utilises crop data of both the cultivars *i.e.* short and long duration at Rahuri (19° 24′ N, 79° 39′ E) during kharif and at Raipur (21° 16′ N, 81° 36′ E) during summer. In addition, data of short duration (kharif) at Dantiwada (24° 19′ N, 72° 19′ E), long duration (kharif) at Durgapura (26° 51′ N, 75° 47′ E) and short duration (summer) at Anand (22° 35′ N, 72° 55′ E) where also utilised. The varieties grown during the experimental period were PM-2, Baisakhi (special), Guj-2, K-851 and RMG-62 for shorter duration and PM-2, Pusa Baisakhi, RMG-325 and RMG-268 for longer duration.

The analysis was basically based on the three phenophases of the crop, *i.e.* germination to boot leaf, bootleaf to pod formation and pod formation to maturity. Average duration of these stages for short and long duration crops were 69 and 91 days, respectively.

Consumptive water use of the crop (*i.e.* ET), crop co-efficient (Kc), water use efficiency (WUE) and radiation use efficiency (RUE) have been computed. In this study, in absence of pyranometer data at the above locations to measure the total or global radiation, the same has been measured indirectly from Angstorm's standard formula utilising the bright sunshine (BSS) hours as $RA = R_0(a + b \cdot n / N)$ where R_0 is the radiation at the top of the atmosphere, n is the actual number of bright sunshine (BSS) hrs. and N is the maximum number of hrs. of BSS which is determined by Smithsonian Table. The constant a and b have been taken from the works of Jagannathan and Ganesan (1967). Not all radiation falling on the crop canopy is used by the crop for its metabolic activity, it is the photosynthetically active radiation (PAR) which is useful for the crop. The total radiation values in this study have been multiplied by 0.45 to get the PAR values (Howell *et al.*, 1983). PAR is closely related to total radiation and the same kind of work has been supported by Nathan, 1982. Using PAR values, RUE or (PAR-UE) has been computed by taking ratio of yield to PAR.

3.1. Water use is defined as beneficial utilization of water by the crop during the crop life span. The water use by moong-bean during kharif, for obvious reason, is less than that during summer for the same cultivar. This is

because of high temperature in summer which resulted in high evapotranspiration values. However, the short duration varieties PM-2, Baisakhi special, Guj-2, K-851 and RMG-62 and the long duration varieties PM-2, Pusa Baisakhi, RMG-325 and RMG-268 during kharif and summer seasons did not show any distinctly identifiable pattern. Thus, at Rahuri though the water use in kharif by short duration cultivar was 258.3 mm, it consumes slightly less (about 250 mm) water in its long duration cultivar. The water used by the crop is evapotranspiration as recorded by the lysimeter. At Dantiwada, the short duration moong-bean uses 294.3 mm of water whereas at Durgapura the long duration uses just 8 mm less water in the same crop season (*i.e.* kharif) than at Dantiwada.

Consumption of water by moong-bean during summer also present somewhat complex picture. The short duration crop at Raipur uses 553.7 mm, but the long duration variety surprisingly uses nearly 5 mm less at the same station.

3.2. Water consumed in each of the 3 phases *viz.*, germination to boot leaf, boot leaf to pod formation and pod formation to maturity and also its percentage (of total water use), is depicted in Table 1.

During kharif in the first phase a short duration crop (variety PM-2) consume 15 to 20 % of the total water use. The demand for water was maximum in the second phase where the crop was actively growing *i.e.*, boot-leaf to pod formation. In this stage it consume slightly more than 1/2 of the total water use. The remaining water was used by the crop in the 3rd phase. The long duration kharif crop uses slightly more water in the 1st and the last phases (nearly 25 to 30 % each) and the remaining water in the 2nd phase. In other words, the crop during boot leaf to pod formation stage in long duration moong-bean consumes significantly less water than a short duration one, though the period of the second phase in both types of crop was identical *i.e.*, 5 weeks each.

Raipur belongs to dry sub-humid zone and the crop in question during summer was raised purely on supplementary irrigation. In the 1st phase, the crop variety Pusa Baisakhi (both short and long duration) uses less than 10 % of the total water use. In the 2nd phase, nearly 1/2 of the water was consumed by the short duration variety, and nearly 40 % by the longer duration variety. Surprisingly, the longer duration crop consumes more than 50 % of water during the pod formation to maturity stages. This phase generally occurs from 2-3 week of May to 3-4 week of June, the period with higher day temperature and lower relative humidity. This explain why the water need of moong-bean was large in the third phase at Raipur.

TABLE 2

Mean water use efficiency (kg/mm/ha)

Station	Kharif		Summer	
	Short duration	Long duration	Short duration	Long duration
Rahuri	3.83	3.88	–	–
Raipur	–	–	1.76	2.63
Anand	–	–	1.49	–
Dantiwada	3.93	–	–	–
Durgapura	–	3.63	–	–

3.3. The WUE has been calculated as the ratio of yield (kg/ha) to total evapotranspiration (mm). The water use efficiency for moong-bean for the two seasons *viz.*, kharif and summer is shown in Table 2. Because of changes in the agroclimatic conditions at these locations, different agronomic practices and use of different varieties, a comparison between stations in the WUE may vary. In spite of the short sample size (as sample was obtained from lysimeters) the analysis revealed that the moong-bean uses water more efficiently during kharif season than in the summer. Generally for each mm of water use, the yield increases by about 3.9 kg/mm/ha at Rahuri.

The short duration moong-bean in summer appears to be rather inefficient in use of water. Its water use efficiency as seen at Anand is nearly 1.5 kg/mm/ha, whereas WUE for the longer duration summer crop was more than 2.5 kg/mm/ha at Raipur. The lower values of WUE in summer for both varieties are due to the fact that the crop has to use a larger amount of moisture in overcoming the stress due to high temperature, desiccating wind and low humidity. Owing to differences in climate, soil, locations and cultivars a rather distorted picture in WUE pattern is seen. Summer crop uses water most inefficiently which perhaps could be improved through introduction of varieties endowed with better crop canopy (Giriappa, 1983) and judicious water management practices.

3.4. The crop coefficient (Kc) in any stage of growth is a ratio of actual evapotranspiration to potential evapotranspiration (ET/PET). It shows vigour of the plant growth in relation to prevailing atmospheric condition. Thus it is not only a function of the phonological stage of the crop but is also specific for each crop.

Fig. 1(a) shows march of the crop coefficient values for moog-bean (kharif) at Rahuri during its life span. As may be seen Kc increases after emergence, rather slowly and gradually, attains a peak value of 1.05 at pod
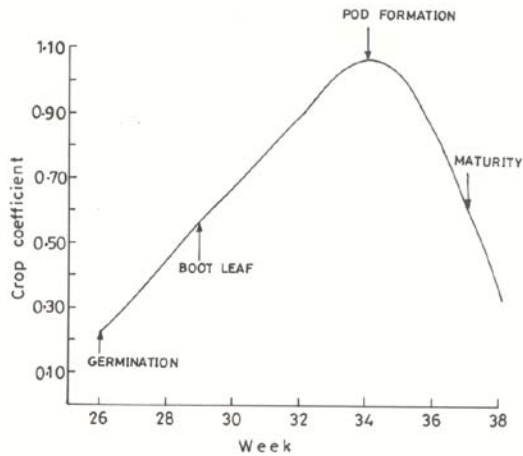
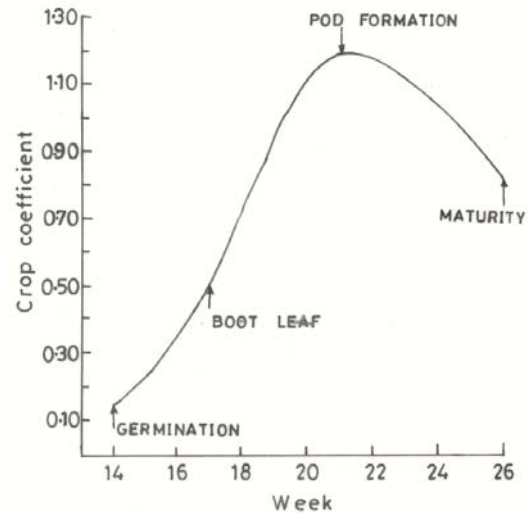**Fig. 1(a).** March of crop coefficient long duration varieties during kharif at Rahuri

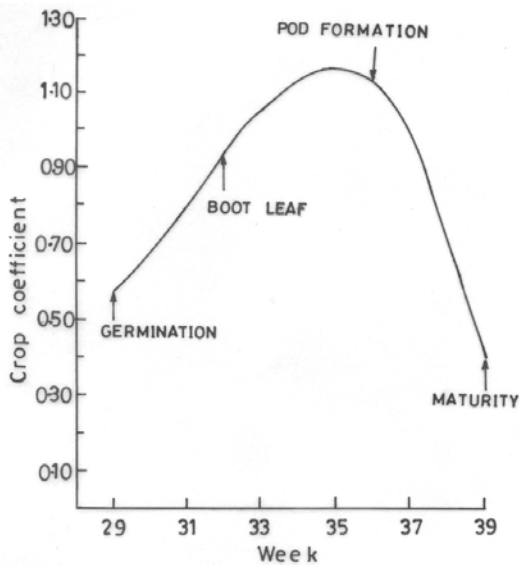**Fig. 1(c).** Long duration varieties during summer crop at Raipur

Fig. 1(b). Long duration varieties during kharif at Durgapura
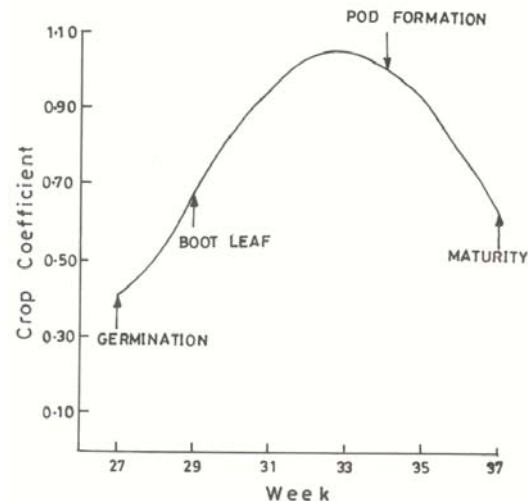

Fig. 1(d). Short duration varieties during kharif at Rahuri

formation. Towards ripening, Kc falls rapidly because the leaves start senescence and are then non actively transpiring. Though moong-bean crop at Durgapura was a long duration (kharif), the pattern [Fig. 1 (b)] seems identical to that observed at [Fig. 1 (a)] for Rahuri. At Raipur [Fig. 1 (c)] a value of 1.2 was reached just before pod formation. Olderman and Frere (1982) reported Kc values for a few crops and observed the peaks at 61-70 days after sowing in maize and soyabean. Das *et al.*, (1996) also showed a peak value of Kc (1.10) for pearl millet at Hissar. Figs. 1 (c&d) represent Kc values for long duration *summer* moong-bean at Raipur and for short duration (kharif) at Rahuri respectively. The pattern generally confirms to that observed in the earlier figures.

The range of values from Fig. 1 at germination, vegetative growth and maturity were 0.15 to 0.58, 0.30 to 0.92 and 0.70 to 1.13 in the present study compared favourably with the values worked out from ET and EP ratio (where EP is pan evaporation) by other research workers.

3.5. Solar radiation, besides soil moisture, plays an important role in the crop growth and its productivity for most parts of the kharif season, when the sky is partially to totally covered by low to medium clouds. PAR-UE has been computed by taking ratio of crop yield to PAR. This would naturally cut-off the insolation drastically and lead to low radiation. In contrast, the summer crop season is mostly cloud-free and would receive largest amount of

TABLE 3

Photosynthetically active radiation (J/cm²)

Station	Kharif		Summer	
	Short duration	Long duration	Short duration	Long duration
Rahuri	696.3	758.7	–	–
Raipur	–	–	839.2	934.4
Anand	–	–	806.7	–
Dantiwada	643.3	–	–	–
Durgapura	–	762.0	–	–

TABLE 4

Photosynthetically active radiation use efficiency, [PA – RUE (g / MJ)]

Station	Kharif		Summer	
	Short duration	Long duration	Short duration	Long duration
Rahuri	0.81	0.73	–	–
Raipur	–	–	0.66	1.25
Anand	–	–	0.38	–
Dantiwada	1.07	–	–	–
Durgapura	–	0.82	–	–

solar energy. In the same crop season, a shorter duration crop cultivar would receive a lower duration radiation compared to a longer duration crop. Not all the radiation received by the plants is useful in its metabolic and photosynthetic activities. Though PAR is closely related to total radiation (Nathan 1982), a factor of 1/2 has been used to convert the latter to the former in this study. (Howell *et al*. 1983) and shown in Table 3.

A shorter duration kharif, moong-bean uses about 700 J at Rahuri and 640 J at Dantiwada of total global radiation. A longer duration variety uses slightly more than 750 J. In summer whereas a shorter duration variety receives nearly 840 J of PAR at Raipur, while it was slightly less i.e. 810 J at Anand, the longer duration variety at Raipur in summer need 930 J.

An ambiguous pattern emerges when efficiency of the crop was worked out from PAR (Table 4). At Rahuri the short and long duration crops (PM-2) have the photo radiation use efficiency of 0.8 and 0.7 g/MJ respectively. In other words, the long duration cultivars use radiation rather slightly more inefficiently. At Dantiwada for the short duration cultivars the efficiency was 1.1 whereas at Durgapura it is 0.8 for longer duration, both during the kharif season. This means even in the generally cloudy kharif season, a short duration variety uses radiation much more efficiently than its long duration counterpart. It was also observed that the RUE was less in summer than in kharif. For the shorter variety the PA-RUE at Raipur was 0.7 whereas at Anand was just 0.4. Surprisingly the PAR-UE for long duration moong-bean at Raipur was nearly double than the short duration one. The PA-RUE was found ranging from 2.0 to 3.0 g/MJ by Gallagher and Biscoe (1978) for C_3, crops and between 1.3 & 1.7 for different cotton cultivars by Rosenthal and Gerik (1991). For rabi sorghum, the PA-RUE was found varying between 1.7 & 2.3 g/MJ as stated by Jadhav *et al*. (1993). Keeping in view that crop in the present study being

different than those studied by others, differences in receipt of the actual radiation due to different geographical locations and the crop being of different durations, the values obtained in this analysis can be said to be comparable favourably with those found by other research workers.

4. The following conclusions can broadly be drawn :

(*i*) Nearly half of the total water was used by short duration moong-bean when the crop was actively grow between boot leaf to pod formation stages, for the long duration crop this value varies from one third to half.

(*ii*) The crop grown in kharif season uses water more efficiently than during the summer.

(*iii*) For obvious reason, less energy was consumed by moong-bean in kharif than in summer.

(*iv*) The peak value of crop coefficient often exceeds 1.0 (meaning thereby that the evapotranspiration exceed its potential value).

(*v*) The photosynthetically active radiation was used more efficiently during the kharif season than in summer.

References

Das, H. P., Kashyapi, A. and Apte, S. G., 1996, "Evapotranspiration and soil moisture balance in relation to yield of pearl millet", *Mausam*, **47**, 1, 73-80.

Giriappa, S., 1983 "Water use efficiency in agriculture", Oxford & IBH Publishing Co., New Delhi.

Gallagher, J. N. and Biscoe, P. V., 1978 "Radiation absorption growth and yield of cereals", *J. Agric. Sci*., **91**, 47-60.

Howell, T. A., Meek, D. W. and Hatfield, J. L., 1983, "Relationship of photosynthetically active radiation to software radiation in the San Joaquinvally", *Agric. Meteorol*., **28**, 157-175.

Jagannathan, P. and Ganesan, H. R., 1967, "Distribution of solar radiation in India", Sci. Report No. 13, India Met. Dept.

Jadhav, J. D., Patil, C. B., Gaikwad, C. B., Mokashi, D. D. and Patil, J. D., 1993, "Radiation – use efficiency in Dryland winter Sorghum (sorghum bicolar) at different sowing periods", *Ind. J. Agril. Sci*., **63**, 12, 842-843.

Mandal, B. K., Dhara, M. C., Mandal, B. B., Das, S. K. and Nandy, R., 1990, "Rice, Mungbean, Soyabean, Peanut, Rice, bean and Blackgram yield under different Inter-cropping Systems", *Agron. J*., **82**, 1063-1066.

Nathan, K. K., 1982, "Note on relationship between photosynthetically active radiation and total radiation", *Annals Arid Zone*, **21**, 4, 259-261.

Olderman, L. and Frere, M. 1982, "A. study of the agroclimatology of the humid tropice of southeast Asia", Tech. Note No. 179, WMO, Geneva.

Rosenthal, W. D. and Gerik, T. J., 1991, "Radiation use efficiency among cotton cultivars", *Agron. J.*, **83**, 655-658.

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