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GROWTH, LIGHT INTERCEPTION, RADIATION USE EFFICIENCY AND PRODUCTIVITY OF MUNGBEAN [*VIGNA RADIATA* (L.) WILCZEK] (FABACEAE) CULTIVARS AS INFLUENCED BY SOWING DATE

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ABSTRACT: The purpose of this study was to assess the influence of sowing date on growth, light interception, radiation use efficiency and productivity of mungbean cultivars. The experiment comprised four sowing dates at ten days interval, *viz*. 08, 18, 28 July and 07 August 2006 and two cultivars, *viz*. Gofa local and MH-97-6. A randomized complete block design with three replications was used. Early sown plants on 8th of July had extended duration to attain physiological maturity, larger leaf area index (LAI) and greater dry matter accumulation. Moreover, early sown plants exceeded in amount of light interception, radiation use efficiency (RUE) and grain yield compared to the late sown ones. The RUE values were 1.74, 1.38, 1.28 and 1.10 g DM MJ^{-1} for the first, second, third and fourth sowing dates, respectively. The decline in yield of last sown mungbean compared to first sowing was about 2% per day of delayed sowing. Cultivar MH-97-6 exceeded Gofa local in LAI and total dry matter. However, their differences in cumulative intercepted PAR, RUE and grain yield were not statistically significant. Grain yield was significantly correlated with growth period moisture (r=0.95), cumulative intercepted light (r=0.98), RUE (r=0.96) and LAI (r=0.82). Early July sowing gave superior performance among tested sowing dates of the main cropping season (meher). However, owing to the crop's short growth duration, it is worthwhile to do further research by including other sowing dates of the short rainy season (belg).

Key words/phrases: Dry matter, Leaf area index, Moisture, Mungbean, Yield components.

INTRODUCTION

Mungbean (*Vigna radiata* (L.) Wilczek) is an important short-duration grain legume crop with wide adaptability, low input requirement and ability to improve the soil by fixing atmospheric nitrogen (Sadeghipour, 2009). It is suited to a large number of cropping systems and constitutes an important source of protein in cereal-based diets (Khattak *et al*., 2001). Mungbean has premium quality over other pulses due to its more palatable, highly nutritive, easily digestible and non-flatulent nature (Khan and Malik, 2001). In Ethiopia, mungbean is a recent introduction and is found in different parts

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of the country (Westphal, 1974). Smallholder farmers in drier marginal environments of Ethiopia grow mungbean (Asrat Asfaw *et al*., 2012) with north Shewa of Kewet woreda as the current belt of production. The crop performs well and gives promising results under hot, irrigated and rainfed conditions of the central Rift Valley and northern Ethiopia (Dereje Nigatu *et al*., 1995). The crop has a great demand in the international market, but there is a huge supply gap due to the existence of limited production in the country (EEPA, 2004). The Ethiopian Commodity Exchange (ECX) has decided to include mungbean as the sixth commodity to be traded on its floor in January 2014 (Addis Fortune, 2014). In order to realize the potential benefit, it is essential to raise production to a level that meets the market demand sustainably. Some of the constraints limiting mungbean production include absence of improved varieties, low yield potential of the crop, lack of research and extension focus, low domestic market and inconsistency of the crop's performance.

There is a need to identify better-yielding adapted cultivars, to develop appropriate agronomic packages and popularize the crop in order to realize the crop's potential. To this end, Southern Agricultural Research Institute has released one cultivar and Hawassa University has also been conducting adaptability tests to identify promising cultivars to the growing areas. These varieties could give relatively better yield if supported with proper agronomic packages. Determining the appropriate sowing date is one of the agronomic strategies with a significant influence on productivity. As Soomro and Khan (2003) indicated, sowing time is one of the non-monetary inputs affecting the growth and yield of field crops under the control of the producer.

Marked effects of sowing date on dry matter production of mungbean (Rahman *et al*., 2002), leaf area development of pea (*Pisum sativum*) (Islam *et al*., 2002), light interception and use efficiency of lentil (*Lens culinaris*) (Azam *et al*., 2002) were reported. Furthermore, significant variation among mungbean cultivars in response to sowing dates were reported (Rahman *et al*., 2002; Soomro and Khan, 2003). However, similar studies on mungbean are lacking in southern Ethiopia as influence of sowing date on crop performance tends to be area-specific because of associated differences in weather and soil variables. Such studies are needed to better understand the physiology of the crop, enhance productivity and promote the crop's popularity. Thus, this research was carried out to assess growth, light interception, radiation use efficiency and productivity response of two mungbean cultivars under different sowing dates at Hawassa, southern

Ethiopia.

MATERIALS AND METHODS

Description of the study area

This experiment was conducted at Hawassa Agricultural Research Centre, south Ethiopia, during 2006 cropping season. Hawassa is located at 07° 05' N and 38° 29' E at an altitude of 1,697 m.a.s.l. The ten years (1996-2005) annual average rainfall was 803.9 mm while minimum and maximum average annual temperatures were 12.9°C and 27.5°C, respectively (NMA, 2006). The site has a sandy clay loam texture with soil organic matter content of 2.95%, 0.14% total N, 63.65 mg kg^{-1} available P, 20.85 cmol kg^{1} CEC and a pH of 7.0 (Meseret Fanta, 2006).

Treatments and experimental design

The treatments consisted of a factorial combination of four sowing dates at 10 days interval, *viz*. 08, 18, 28 July and 07 August 2006 and two mungbean cultivars, *viz*. Gofa local and MH-97-6. The four sowing dates (SD) were designated as SD1 (08 July), SD2 (18 July), SD3 (28 July) and SD4 (07 August). The experiment was laid out in randomized complete block design in three replications. Size of each plot was 9 m^2 (3 m x 3 m).

Agronomic management

Prior to sowing, the land was finely prepared and uniformly fertilized at a rate of 23 kg P_2O_5 and 9 kg N ha^{-1} in the form of diammonium phosphate (DAP) fertilizer. Two seeds per hill at a spacing of 30 cm between rows and 10 cm between plants were sown. Thinning was done a week after emergence to allow one plant per hill. Weeds were controlled by hand as often as required. Moreover, a shallow cultivation was carried out at 30 days after emergence.

Sampling and data collection

Five randomly sampled plants were harvested from each plot at two weeks interval starting from 15 up to 105 days after emergence (DAE). Sampled plants were separated into leaves, branches, stem and pod. The leaf area was electronically measured in laboratory with portable area meter (model LI-3000A, Li-Cor, Lincoln, USA). The leaf area index (LAI) was determined as the ratio of leaf area to ground area occupied by the sample plants. Then the samples were oven dried for 48 hours at 70°C for dry matter determination.

Incoming radiation was continuously measured on a daily basis at the site using a quantum sensor and a microvolt integrator (Delta-T Devices, England). Amount of incoming Intercepted Photosynthetically Active Radiation (IPAR) by the canopy at each sampling date was calculated by using:

$$IPAR_i = PAR_i * GC_i$$

Where $IPAR_i$ is amount of incoming PAR intercepted at i^{th} sampling date; PAR_i is recorded PAR above the canopy at i^{th} sampling date and GC_i is ground cover of the crop at i^{th} sampling date.

The proportion of GC_i starting from 15 DAE was measured using a grid at two weeks interval. The grid was a 0.9 m x 0.5 m dimension wooden frame divided into 100 equal sections. During measurement the grid was placed on the top of mungbean canopies. Only those sections more than half-filled with green leaves were counted by observing vertically above the grid. Then IPAR was calculated by assuming a 1:1 relationship between % ground cover and % light intercepted (Cadersa and Govinden, 1999; Admasu Tsegaye and Struik, 2003).

The cumulative intercepted PAR (CIPAR) during the growth periods was determined by summing up intercepted light as follows:

$$CIPAR = \Sigma n\ [(IPAR_{n-1} + IPAR_n)/2]\ (t_n - t_{n-1})$$

Where $IPAR_{n-1}$ is IPAR at sampling time t_{n-1} and $IPAR_n$ is IPAR at sampling time t_n.

The efficiency with which the crop used intercepted radiation for dry matter production was calculated as the slope of the linear relationship, forced through the origin, between cumulative total dry matter (g m^{-2}) and cumulative intercepted PAR (MJ m^{-2}). Besides, phenological data such as days to flowering and maturity were recorded. Days to flowering were taken by counting the number of days when 50% of the plants per plot had opened flowers. Days to physiological maturity were recorded when 85% of all pods per plot lost chlorophyll and turned black.

Data for yield components such as number of pods, 1000 grain weight and number of seeds per pod were taken from five randomly selected plants of each plot. Grain yield and final aboveground biomass was measured from the final harvest made on the two central rows with an area of 1.8 m^2 (3 m x 0.6 m). Grain yield was adjusted to 10% moisture content. Three consecutive harvestings were made for grain yield to prevent shattering of early ripened pods.

Data analysis

The data were analyzed using the General Linear Model of Statistical Analysis System software (SAS version 6.12, 1997). Significant differences among treatment means were compared using least significant difference test at 5% level of significance.

Weather condition

The area received an annual rainfall of 1,198 mm and had minimum and maximum temperature records of 13.9°C and 27.1°C, respectively. Amount of rainfall progressively decreased as the sowing date was delayed (Table 1). The weather data during the growing period showed that first sown mungbean received 14, 23 and 37% higher rainfall compared to second, third and fourth sowing dates, respectively.

Table 1. Summary of weather conditions of the experimental site across sowing dates during the crop growth period (July - November, 2006).

		Mean temperature (°C)		
Sowing date	**Total rainfall (mm)**	**Maximum**	**Minimum**	**Mean**
08 July	583.3	25.1	23.9	19.5
18 July	452.2	25.1	13.9	19.5
28 July	430.8	25.0	13.8	19.4
07 July	386.7	26.1	13.7	19.9

RESULTS

Crop development and growth parameters

Sowing date showed a significant effect on days to flowering and days to physiological maturity (Table 2). Maximum days to flowering was 64 and the minimum was 57, which were recorded for the second and fourth sowing dates, respectively. The last sown plants reached flowering faster by 7 days than second sown plants. Moreover, first sown mungbean reached physiological maturity 112 days after emergence and this was late by 15 days compared to the third and the fourth sowing dates. Generally, flowering and physiological maturity were enhanced as the sowing was progressively delayed. Significant differences for days to flowering but not for days to physiological maturity were observed between cultivars. However, the difference on days to flowering was very small, which was less than a full day. There was a significant cultivar by sowing date interaction for days to flowering though the effect was not large enough to change the ranking of the main effects.

Sowing date had no significant effect on plant height (Table 2). Differences in plant height were observed between the two cultivars tested. Cultivar MH-97-6 showed longer plant height (59 cm) compared to Gofa local cultivar (52 cm).

Table 2. Crop phenology, growth parameters and intercepted light by mungbean as influenced by sowing date and cultivar.

Treatments	Days to flowering	Days to maturity	Plant height (cm)	Total dry matter (t ha^{-1})	Cumulative Intercepted PAR (MJ m^{-2})
Sowing date					
08 July	60.0^{b}	112.3^{a}	52.0^{a}	4.308^{a}	454.12^{a}
18 July	64.0^{a}	103.8^{b}	56.5^{a}	3.249^{b}	408.49^{b}
28 July	58.0^{c}	97.6^{c}	55.2^{a}	2.967^{b}	403.45^{b}
07 July	57.3^{d}	97.6^{c}	58.0^{a}	3.153^{b}	406.1^{b}
$LSD_{0.05}$	**0.5**	**3.3**	**NS**	**0.61**	**44.18**
Cultivar					
MH-97-6	60.1^{a}	104.0^{a}	59.3^{a}	3.736^{a}	433.94^{a}
Gofa local	59.5^{b}	101.7^{a}	51.9^{b}	3.104^{b}	420.6^{a}
$LSD_{0.05}$	**0.35**	**NS**	**4.9**	**0.43**	**NS**
CV (%)	**0.6**	**2.6**	**10.1**	**14.4**	**8.34**

Means with the same letter within columns are not significantly different at P<0.05.

Sowing date significantly influenced leaf area index (LAI) except for 75 days after emergence (Fig. 1). The peak LAI was attained at 90 DAE irrespective of the treatments and thereafter LAI declined. The maximum LAI was recorded from the first sowing followed by the second sowing. Comparison of peak LAI showed that first sown mungbean resulted in 40 and 32% more LAI compared to third and fourth sowing dates, respectively.

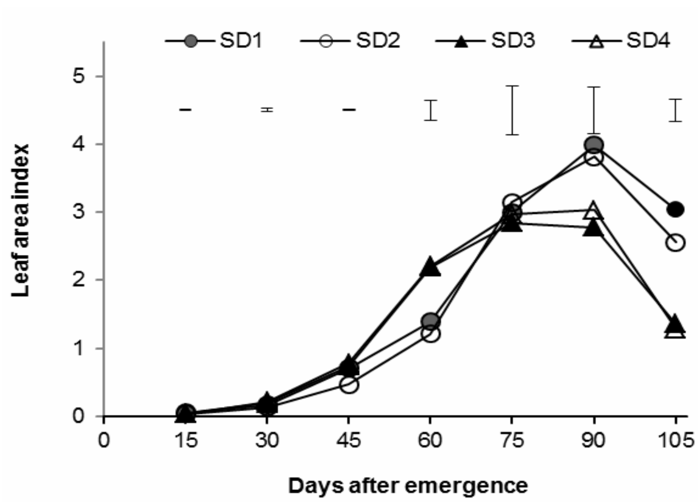

Fig. 1. Leaf area index of mungbean in response to different sowing dates. SD1, 08 July; SD2, 18 July; SD3, 28 July; SD4, 07 August.

Significant differences in LAI between mungbean cultivars were also observed in all samplings, except 30 and 45 DAE (Fig. 2). Cultivar MH-97-6 showed higher LAI over Gofa local starting from 60 DAE up to physiological maturity. Cultivar MH-97-6 reached critical LAI at 75 DAE while Gofa local reached at 90 DAE. In both the varieties LAI began declining after attaining maximum values of 3.76 and 3.05 for MH-97-6 and Gofa local, respectively at 90 DAE. Peak leaf area index of MH-97-6 was higher by 23% compared to Gofa local.

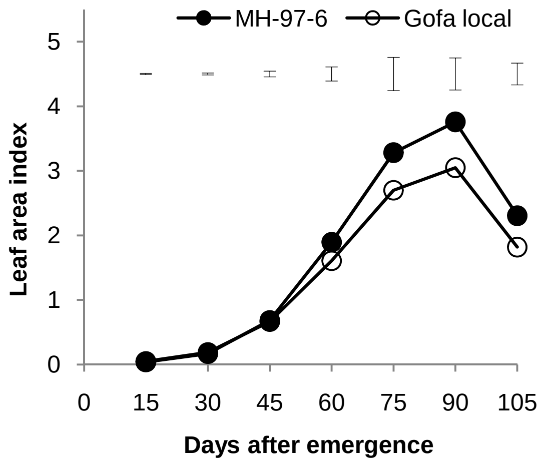

Fig. 2. Leaf area indices of two mungbean cultivars, averaged over four sowing dates.

Sowing date significantly influenced total dry matter production (TDM) of mungbean (Table 2). The highest total dry matter was produced from first sowing date, while the rest of the sowing dates did not show statistically significant differences. First sown mungbean produced 33, 38 and 45% larger final total dry matter compared to second, third, and fourth sowing dates, respectively. Generally, changes in dry mater production were slow until 45 DAE in all the treatments (Fig. 3). Thereafter, there was a remarkable increase until 105 DAE in the first two sowing dates and until 90 DAE in the last two sowing dates after which dry matter production showed a declining trend.

Significant differences between the two cultivars for total dry matter production were observed (Table 2). However, the sequential sampling on the two cultivars showed that differences in dry matter accumulation at all samplings were non-significant except at 105 DAE (data not included). The final dry matter produced by MH-97-6 (3.73 t ha^{-1}) was greater by 20% compared to Gofa local (3.10 t ha^{-1}).

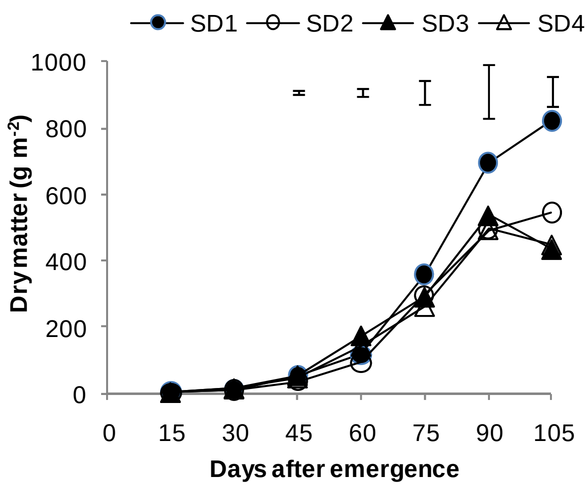

Fig. 3. Dry matter accumulation of mungbean at different sowing dates throughout the growth period. SD1, 08 July; SD2, 18 July; SD3, 28 July; SD4, 07 August 2006.

Light interception and radiation use efficiency

Differences in the amount of cumulative intercepted PAR were observed among sowing dates (Table 2). The amount of cumulative intercepted PAR by first sowing was 454 MJ m^{-2} compared to 403 MJ m^{-2} for the third sowing date, which was the lowest. Accordingly, first sown mungbean plants intercepted 11, 13 and 12% more PAR than second, third and fourth sowing dates, respectively. The difference in intercepted PAR between the two cultivars was not significant. However, amount of PAR intercepted by MH-97-6 (434 MJ m^{-2}) was slightly greater than Gofa local (421 MJ m^{-2}) (Table 2).

There were differences in RUE among the sowing dates (Fig. 4 A, B, C and D). Radiation use efficiency reduced progressively as sowing date was delayed. The RUE (±S.E) values obtained were 1.74 ± 0.09 for the first, 1.38 ± 0.06 for the second, 1.28 ± 0.10 for the third and 1.10 ± 0.06 g MJ^{-1} PAR for the fourth sowing dates. Mungbean under first sowing showed 26, 36 and 58% higher RUE values compared to second, third and fourth sowing dates, respectively.

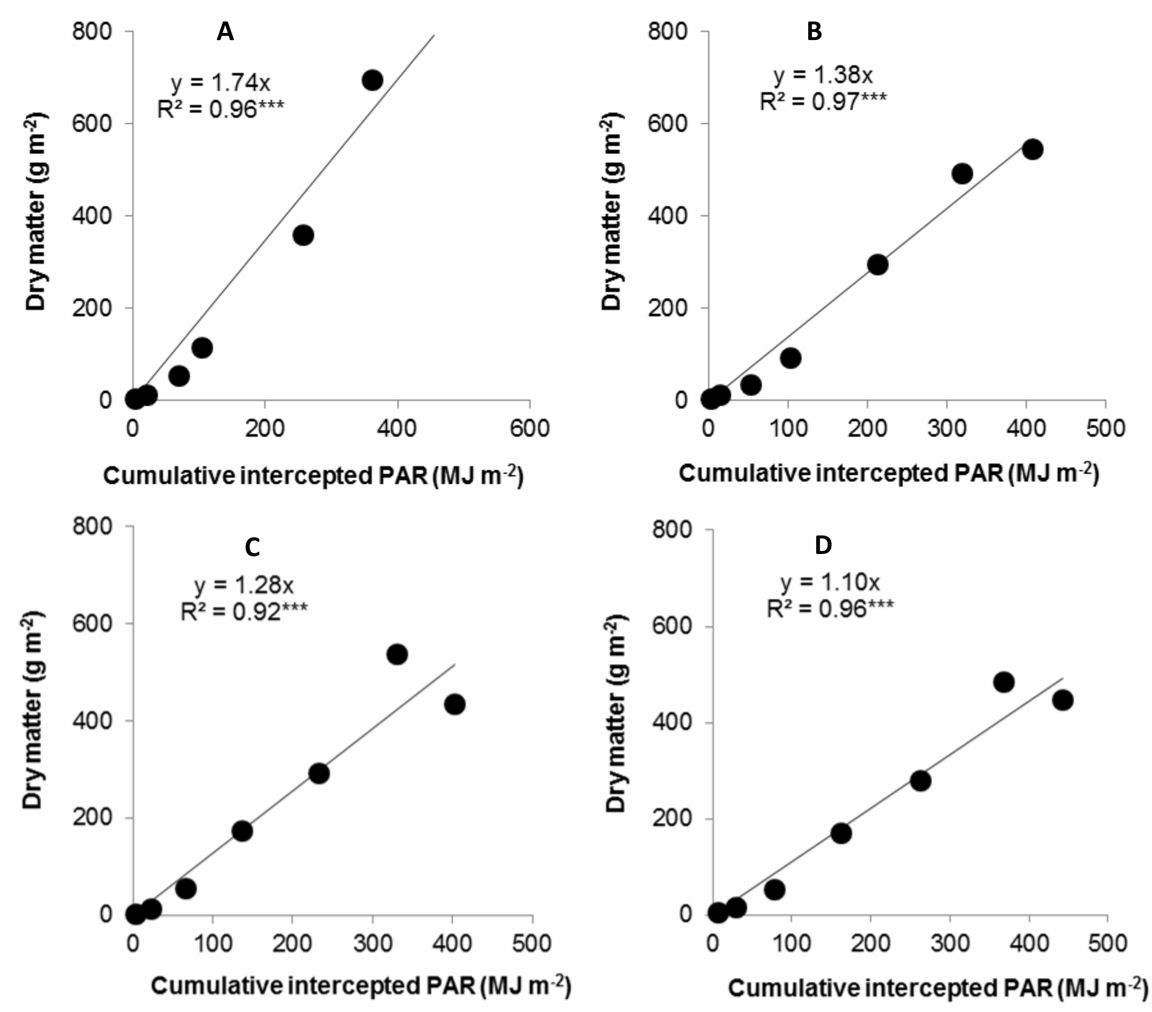

Fig. 4. Relationship between dry matter production and cumulative intercepted PAR in mungbean for (A) 08 July, (B) 18 July, (C) 28 July and (D) 07 August 2006 sowing dates. ***, significant at P=0.001.

Similar RUE values were observed, more or less, between the two cultivars (Fig. 5 A and B). The RUE (±S.E) values obtained, averaged over sowing dates, were 1.39 ± 0.06 for MH-97-6 and 1.33 ± 0.09 g MJ^{-1} PAR for Gofa local.

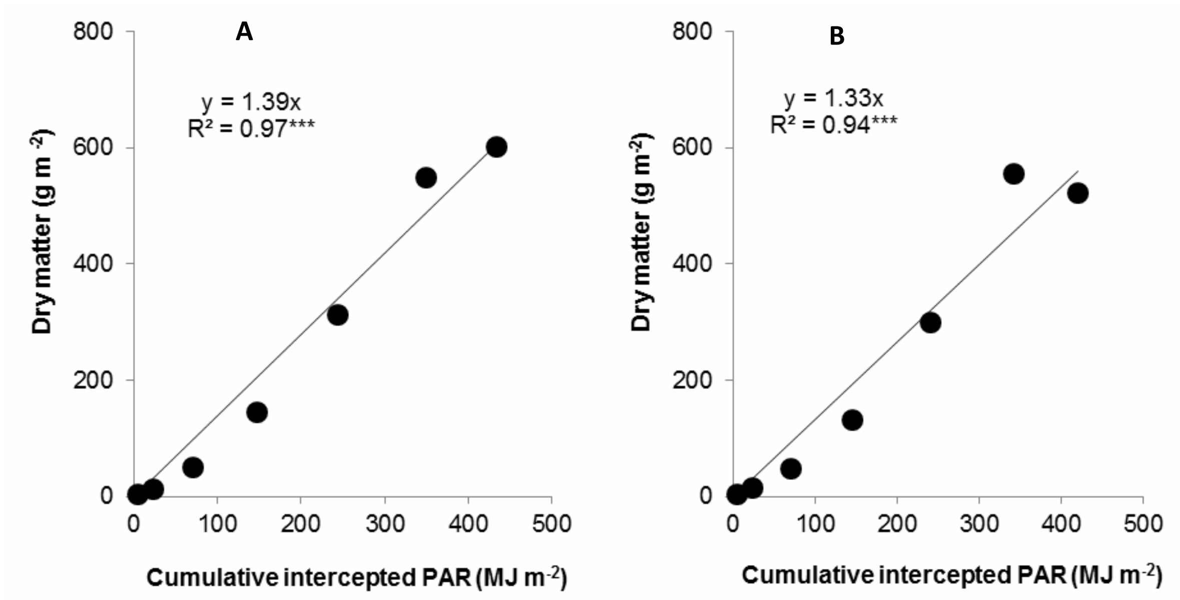

Fig. 5. Relationship between dry matter production and cumulative intercepted PAR in mungbean cultivars (A) MH-97-6 and (B) Gofa local. ***, significant at P =0.001; values are average of four sowing dates.

Grain yield, yield components and harvest index

Grain yield from the first sown mungbean was significantly different from other sowing dates while yield from the remaining sowing dates were not statistically different among each other (Table 3). First sown mungbean produced highest yield (1.79 t ha^{-1}), greater by 55% compared to the last sowing. The result also revealed that the decline in yield of last sown mungbean compared to first sowing was about 2% per day of delayed sowing. The maximum yield produced from the first sowing was 1.79 t ha^{-1} followed by 1.30, 1.18 and 1.16 t ha^{-1} for the second, third and fourth sowing dates, respectively.

The grain yield difference between the two cultivars barely passed the 5% significance level (P=0.052). Cultivar MH-97-6 produced 18% higher grain yield than Gofa local (Table 3). The yield obtained from MH-97-6, averaged over sowing dates, was 1.47 t ha^{-1} while Gofa local produced 1.25 t ha^{-1}.

Table 3. Grain yield, yield components and harvest index of mungbean as affected by sowing date and cultivar.

Treatments	Grain yield (t ha^{-1})	Pod No. plant^{-1}	Seed No. pod^{-1}	1000 seed wt (g)	Harvest index
Sowing date					
08 July	1.79^{a}	35.9^{a}	9.68^{a}	35.2^{a}	0.41^{a}
18 July	1.30^{b}	29.3^{b}	8.96^{a}	34.2^{a}	0.40^{a}
28 July	1.18^{b}	26.6^{b}	9.76^{a}	35.6^{a}	0.39^{a}
07 August	1.16^{b}	26.8^{b}	9.70^{a}	36.0^{a}	0.37^{a}
$LSD_{0.05}$	**0.31**	**6.34**	**NS**	**NS**	**NS**
Cultivar					
MH-97-6	1.47^{a}	32.18^{a}	9.8^{a}	34.7^{a}	0.39^{a}
Gofa local	1.25^{a}	27.16^{b}	9.2^{a}	36.0^{a}	0.39^{a}
$LSD_{0.05}$	**NS**	**4.48**	**NS**	**NS**	**NS**
CV (%)	**19.0**	**17.2**	**9.1**	**5.05**	**11.9**

Means with the same letter within columns are not significantly different at $P<0.05$.

Sowing date significantly affected number of pods per plant, but not grain weight and number of seeds per pod (Table 3). First sown mungbean produced 23, 35 and 34% more pods per plant compared to second, third and fourth sowing dates, respectively.

Significant variations between cultivars were observed for number of pods per plant but not for seed number per pod and seed weight (Table 3). Cultivar MH-97-6 produced 19% more number of pods per plant compared to Gofa local. Neither planting date nor cultivars affected harvest index (Table 3).

DISCUSSION

Crop development and growth parameters

Days to flowering and physiological maturity were enhanced as sowing date was delayed. The accelerated flowering and physiological maturity observed with delayed sowing could not be explained by temperature change, as there were no appreciable differences in temperature among the various sowing dates. However, this may be a result of lower moisture availability at later sowing dates leading to water stress that may accelerate senescence. The result was in agreement with the findings of Ihsanullah *et al*. (2002) on black gram (*Vigna mungo*) and Geletu Bejiga *et al*. (1994) on chickpea (*Cicer arietinum*) who reported earlier flowering and maturity on a late sown crop. In addition, Getachew Lemma *et al*. (2009) has reported a tendency of earlier flowering and enhanced rate of maturation on plants under water stress condition, in cowpea (*Vigna unguiculata*).

Leaf area index (LAI) is one of the major characteristics influencing dry matter production and grain yield, which was significantly influenced by sowing date. Accordingly, maximum leaf area indices were observed in the early sown mungbean compared to late sown ones. This could be related to more number of leaves per plant due to longer vegetative growth period from earlier sowing. Similarly, Islam *et al*. (2002) noticed higher LAI in podded pea (*Pisum sativum*) from early sowing as a result of larger leaf with more number of leaflets due to extended period received for vegetative growth.

Between the two cultivars, MH-97-6 showed higher LAI over Gofa local during most of the growth period. The higher LAI was partly related with more branch number produced by MH-97-6 compared to Gofa local (data not shown). The decline in LAI on both mungbean cultivars at the later part of growth is related to senescence of the leaves, which is associated with the remobilization of photosynthates to the developing pods. The result was in agreement with Islam *et al*. (2002) in podded pea and Biswas *et al*. (2002) in black gram, who reported decreased LAI due to leaf senescence and abscission of leaves.

Greater dry matter accumulation was observed from first sowing and followed the trend of leaf area development, generally. The better performance of early sowing in dry matter production was closely related with greater LAI achievement. This enabled the plants to intercept more of the available radiation for the production of assimilates. The subsequent decrease in dry matter production at latter stages of crop growth was also associated with reduction in LAI. There was a significant positive correlation between leaf area index and dry matter production (r=0.45). The results in this experiment were consistent with those of Rahman *et al*. (2002), who reported higher dry matter accumulation on mungbean from early sowing as a result of better vegetative growth and greater PAR interception. Cultivar MH-97-6 produced higher total dry matter than Gofa local. The higher values of LAI and intercepted PAR for MH-97-6 over Gofa local might have contributed for the larger total dry matter accumulation in this cultivar. Varietal differences in dry matter production were reported in mungbean by Rahman *et al*. (2002).

The growth of mungbean as observed in leaf area index and dry matter accumulation has shown a sigmoid pattern. Both parameters have shown slow growth for the first 45 days after emergence. A similar growth pattern was reported in mungbean involving four genotypes by Mondal *et al*.

(2011). Such extended early slow growth might have contributed for the low yield potential of the crop. For instance, the highest leaf area index attained at flowering was 2.2, which is lower than the LAI required for full light interception. The critical leaf area index of 3 which is needed for full interception is achieved at about two weeks after flowering. Asaduzzaman *et al*. (2008) observed that mungbean plant as a pulse crop showed a phase of slow dry matter production in early growth stage up to 40 days after sowing. This could lead to yield limitation because of incomplete light interception as productivity is linearly related with cumulative intercepted radiation.

Light interception and radiation use efficiency

Crop growth can be considered as the product of incoming solar radiation, the fraction of that intercepted by the crop and the efficiency with which the intercepted radiation is used to produce biomass (Nam *et al*., 1998). The result of this study indicated that the effect of late sowings were primarily expressed through reduced light interception and smaller RUE. Reduced light interception may have been associated with lower LAI and shorter growth duration. This may indicate that sowing date affects productivity mainly through limiting the size and duration of the photosynthetic apparatus. As indicated by Idinoba *et al*. (2002), increased leaf area development resulted in improved occupancy of inter-plant spaces and consequently enhanced percentage of radiation interception, which in turn resulted in an increased rate of dry matter production. Comparable report was made by Azam *et al*. (2002) in lentil, in which they observed more PAR interception from early sowing due to longer growth duration and greater canopy size, over late sowing.

Differences in total intercepted PAR between cultivars were not significant though cultivar MH-97-6 intercepted more PAR compared to Gofa local. Cultivar differences on light interception depend on the extent of variation in morphology and growth duration of the cultivars concerned. For instance, Walelign Worku and Walelign Demisie (2012) did not find significant difference in amount of intercepted radiation in pigeon pea (*Cajanus cajan*) while Muchow and Charles-Edwards (1982) observed significant variation among mungbean cultivars.

Radiation use efficiency (RUE) is a derived variable based on the ratio of accumulated crop mass and intercepted radiation, and it is a key measure of the photosynthetic performance of crops. Differences in RUE among sowing dates were recorded, which showed reduced RUE under late sowing. The result was in conformity with Azam *et al*. (2002) who observed decreased RUE for lentil with delayed sowing. The reduction in RUE in late sowing may be associated with water stress. A highly significant correlation between moisture supply during the growing period and radiation use efficiency (r=0.99) was observed. Similarly, a reduction in RUE under water stress conditions in common bean (Walelign Worku and Skjelvåg, 2006) and three-grain legumes (Kinde Tesfaye *et al*., 2006) were reported. The RUE values found in this experiment for the optimum sowing date were comparable to the reported mungbean values of 1.73 g MJ^{-1} PAR (Muchow and Charles-Edwards, 1982), under rain-fed growth conditions. However, Muchow *et al*. (1993) reported slightly higher RUE value probably owing to the fact that the experiment was conducted under well watered conditions.

Cultivar variation for RUE was minimal compared to the differences among sowing dates. Similarly, Silim and Saxena (1992) did not find significant differences in RUE between faba bean genotypes. Moreover, a great deal of stability in RUE has also been found among peanut cultivars (Wright *et al*., 1993). On the other hand, significant variations in RUE of mungbean cultivars (Muchow and Charles-Edwards, 1982) and pigeon pea genotypes (Nam *et al*., 1998) were reported. Muchow and Charles-Edwards (1982), in mungbean cultivars, showed that differences were either in the potential photosynthetic activities of cultivars or the partitioning in dry matter between the roots and shoots.

Grain yield and yield components

Early sown mungbean produced higher grain yield over later sowings. The higher yield from early sowing was due to better moisture supply as it was positively and significantly correlated with grain yield (r=0.95). The good moisture supply led to vigorous vegetative growth, which was expressed by higher LAI, greater dry matter accumulation and increased number of pods per plant. Besides, increased PAR interception and better RUE contributed to the higher grain yield obtained from early sowing. This was indicated with a positive significant correlation of grain yield with radiation use efficiency (r=0.96) and cumulative intercepted PAR (r=0.98). Soomro and Khan (2003) reported a better yield of mungbean from early sowing due to better rainfall distribution, vigorous vegetative growth prior to onset of flowering, increased pod formation and grain filling. Moreover, Rahman *et al*. (2002) and Sarkar *et al*. (2004) obtained higher grain yield of mungbean from early sowing due to increased number of branches and pods per plant, and higher number of seeds per pod. Yield advantages have been reported from early planting compared to late plantings due to better moisture availability in other pulses in Ethiopia such as common bean (Ohlander, 1980) and chickpea (Geletu Bejiga and Abebe Tulu, 1982; Geletu Bejiga *et al*., 1997).

Grain yield was not significantly different between the two cultivars though cultivar MH-97-6 had relatively higher yield. With significantly greater number of pods and branches per plant that were significantly correlated with grain yield, MH-97-6 might be preferred to Gofa local.

Early sown mungbean produced higher number of pods per plant. Late sown plants received less amount of moisture and ended up with less vegetative growth leading to reduced canopy size. For this reason, all produced pods might not have equally competed for limited supply of assimilates. As a result, lately developed pods might have been abscised due to source limitation and this contributed to the reduced pod number. Sarkar *et al*. (2004) and Soomro and Khan (2003) reported highest pod number per plant from earlier sowing dates in mungbean.

The experiment showed the possibility of enhancing mungbean productivity by observing optimum sowing date, which contributed by improving canopy size, amount of intercepted radiation and radiation use efficiency. Early July planting showed superior performance among the four tested sowing dates of the main cropping season (meher). However, owing to the crop's short growth duration, it is useful to do further research by including other sowing dates of the short rainy season (belg).

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