IMPACT OF TREE MANAGEMENT ON GROWTH AND PRODUCTION BEHAVIOUR OF INTERCROPS UNDER RAINFED AGROFORESTRY

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Abstract: This investigation was aimed to evaluate the impact of changes in incident radiation through crown modification on crop performance. Different shade intensities created through tree crown management significantly affected growth, physiological attributes and yield related parameters in *Vigna mungo* (syn. *Phaseolus mungo*) and *Pisum sativum* grown as understorey field crops with *Morus alba* under rainfed conditions. The crown management treatments namely, no crown removal, 25, 50 and 75% crown removal resulted in 91, 85, 63 and 47% shade, respectively. Plant height, number of flowers, leaf area of crops was reduced significantly with the increase in shade intensities and decrease in distance from the tree trunk. Higher pods per plant, grains per pod, grain yield and harvest index were observed at lower shade intensities. Growth and yield was maximum in open control (without tree); while unmanaged canopy of *Morus* trees caused overall yield reduction of 42% beneath canopy up to 3 m distance from the tree trunk. The crown management regulated physiological attributes in the field crops. The maximum photosynthetic rate was recorded for open plot plants, which declined in plants beneath dense canopy. The amount of water transpired from the crop plants decreased with increase in shade intensity. The conversion efficiency was maximum for plants growing as sole crop which decreased with increasing shade intensities. Based on the results of present investigation, it can be recommended that out of the four tree canopy management options tried i.e. 0, 25, 50 and 75% crown removal; 75% crown removal causing least negative effects on crop growth and yield may be adopted as a compromised crown management practice.

INTRODUCTION

Managing trees, especially in Agroforestry, is of utmost importance, otherwise they may become too large and/or unsuitable. The integration of trees on the farmland creates complex biological interaction, which may not necessarily result in yield advantage. The tree architecture plays an important role in deciding the growth of understorey crops. The crown spread affects not only soil properties and microsite environment, but also the performance and yield potential of associated crops. There is ever increasing need to integrate fast growing multipurpose tree species on the farmland as to overcome fuel and fodder shortages. Reports are available where the positive and/or negative impacts of the presence of tree canopies on the performance of understorey vegetation have been indicated (Huxley *et al.*, 1989; Kessler, 1992; Ong *et al.*, 1991; Puri and Bhargwa, 1992; Lakshmma and Rao, 1996; Rao *et al.*, 1998 and Gillespie *et al.*, 2000; Thakur and Dutt, 2003). The major management options for manipulating trees in Agroforestry are based on the alteration of light (solar radiation) profile and moisture distribution. The options for managing trees are many e.g. pruning, coppicing, pollarding, lopping etc. The impacts of such practices can some times have drastic implications as the removal of above ground portion results in enormous decrease in photosynthesis and the tree may die. In addition, canopy management will often have direct bearing on the root characteristics as well as growth, vigour and biomass production of the tree itself (Thakur and Sehgal, 2000, 2003). The quantity as well as quality of solar radiation transmitted by the tree canopy decides growth and productivity potential of underlying field crops (Fisher and Palmer, 1984; Singh, 1994). Most of the agricultural crops grown under Agroforestry trees are shade sensitive. Any Agroforestry system with four to five year old multipurpose tree species as one of the major components may render the system less productive and/or uneconomical due to developing canopies. The unmanaged tree canopy not only reduces the productivity of agricultural crops, but in most cases deteriorates the quality of the produce as well (Duguma *et al.*, 1988)). The available literature shows positive response in some crops and inverse trends with other when raised under the tree species. The understanding of various interrelated and interdependent processes including above ground and below ground interactions between the woody and non-woody component is necessary. Keeping in view the shade as an important and critical factor affecting production and compatibility in an Agroforestry system, the present study was undertaken to find out the possibility of growing two important leguminous crops *Vigna mungo* and *Pisum sativum*, with the multipurpose tree species *Morus alba*. This species is an important broad-leaved fodder and fuel tree species with dense canopy, which is preferred by the farming community on their farmland. *Morus alba* was chosen as a woody overstorey tree component to test the hypothesis that modification of shade intensity by crown removal would significantly influence the growth, yield and physiological status of associated understorey crops under rainfed conditions.

MATERIALS AND METHODS

The study site is located at Nauni 30°51'N latitude and 76°11'E longitude, 15 km South of Solan town in North-West Himalayan region in Himachal Pradesh. The site represents a transitional zone between sub-tropical to sub-temperate region with an elevation of 1200 m. The area receives an annual rainfall of 1150 mm, most of which is received during the months from July to August. The maximum and minimum temperature during the crop growing season (July to October) was 29.2 and 17.9°C, respectively and rainfall 357.4 mm. The soil of the experimental site is brown and texture is sandy loam up to 30 cm depth that belongs to Typic Eutrochrept at subgroup level as per Soil Taxonomy of USDA. The soil is medium in available nitrogen (278.4 kg ha^{-1}), high in available potassium (218.1 kg ha^{-1}) and phosphorus (19.5 kg ha^{-1}) having a soil pH of 6.8; organic carbon (0.75%).

Five year old uniform trees of *Morus alba* (Linn.), standing as rows in East-West direction, with plant to plant spacing of 5 m and row to row 8 m were given four canopy management treatments in the month of November, 2000 for creating different levels of shade intensities. The average height of *Morus* trees at the time of imposing treatments was 4 m and leaf area index 3.06. *Morus* trees were planted in 1995 with the aim to raise fuel and fodder and diversify production. The trees were allowed to grow for 5 years without any tree canopy management. The treatments were, (i) no crown removal; (ii) 25 per cent crown removal; (iii) 50 per cent crown removal; (iv) 75 per cent crown removal and (v) open control (without tree), located in the same field 10 m away from the trees. The treatments were completely randomized consisting of 8 trees per treatment.

Two field crops i.e. *Vigna mungo* and *Pisum sativum* were grown with *Morus alba* in North-South direction on either side of the trees under comparable different crown management treatments. The field was ploughed thoroughly and the seeds of both the crops were sown in lines with row to row distance of 30 cm. *Vigna mungo* seeds were sown in July and *Pisum sativum* in August. The fertilizer in the form of Calcium Ammonium Nitrate (CAN) 26 kg ha^{-1}, P_2O_5 (81 kg ha^{-1}) and K_2O (21 kg ha^{-1}) were broadcasted in to the *V. mungo* plots at the time of sowing. In *P. sativum* the amounts of N:P:K were 46:70:40 kg ha^{-1}. Nitrogen was applied in two split doses, one at the time of sowing and another after one month. All the agrotechniques necessary to maintain field crops were adopted. The experiment was laid out in randomized block design (factorial) with four replications and plot size was 7.50 x 4.90 m. Eight *Morus* trees per canopy management treatment consisted of tree component in the system. Each plot contained single *Morus* tree.

Ten randomly selected plants per replication from each plot at each distance (1, 2, 3 m) on either side of the tree trunk (55 days after sowing) were used for estimating plant height and flower number per plant. The leaf area of fully expanded 20 leaves from 10 randomly selected plants per replication was taken using leaf area meter (CI-203, INC USA). The leaf area has been expressed as cm^2 per leaf and each value is the mean of three replications. The number of pods per plant and the number of grains per pod were determined in ten randomly selected plants per replication at each distance. The grain yield from 1 m^2 plot at each distance (1-3 m) from the tree trunk was recorded and given as g m^{-2}. The harvest index was calculated by dividing grain yield with biological yield.

The photosynthetic rate (μ mol m^{-2} s^{-1}) was recorded between 10:00 to 13:00 hours at flower initiation using a pre-programmed portable photosynthesis system (CI-301, CID. INC. USA). Each value is the mean of 4 replications (5 leaves per replication). The amount of water transpired (m mol m^{-2} s^{-1}) from the crop plant was also determined by using CI-301 photosynthesis system. The conversion efficiency (ratio of photosynthesis to photosynthetically active radiation) for both the crops was calculated as under:

$$\text{Conversion efficiency}(\%) = \frac{\text{Photosynthesis}\ (\mu\ \text{mol}\ CO_2\ m^{-2}\ s^{-1})}{\text{PAR (mol photon}\ m^{-2} s^{-1})} \times 100$$

The transmitted photosynthetically active radiation (PAR, μ mol m^{-2} s^{-1}), used for determining conversion efficiency, was determined by placing PAR sensors between 1-3 m beneath canopies. Light transmission (shade intensity) was determined using PAR sensors and lux meters. The data was taken at five different times on cloudless day at 930, 1130, 1330, 1530 and 1730 hours at 10 day interval from July to September.

The data was statistically analysed as a randomized block design by using the technique of analysis of variance (Gomez and Gomez, 1984) to test for significant differences between treatments.

RESULTS

The crown management adopted during the present study created different shade intensities to the associated field crops. For example, no crown removal in *M. alba* resulted 91.29 per cent shade from July to September, the growing period of both the field crops. Shade intensities declined with increase in percentage of crown removal (Fig. 1). Average shade intensity beneath canopy in 75 per cent crown removal was 47.29 per cent from July to September.

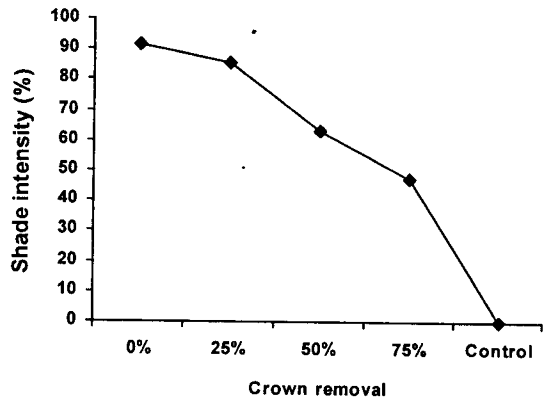

Fig. 1. Influence of crown management on shade intensities in Agroforestry system.

The plant height of both *V. mungo* and *P. sativum* was significantly influenced by shade intensities compared to full sun in control plots (Table-1). The maximum plant height in *V. mungo* (55.6 cm) was observed in sole crop followed by 75 per cent crown removal at 3 m distance from the tree trunk (52.4 cm). The minimum plant height (34.0 cm) was under no crown removal at 1 m distance from the tree trunk. In *P. sativum* the maximum plant height (52.5 cm) in open plots was followed by a decline in plants under 75 per cent crown removal, where plant height at 3 m distance from the tree trunk was 47.7 cm and 43.2 cm at 1 m distance under no crown removal (Table -1).

The increasing shade intensities and decreasing distance from the trees resulted significantly decreased number of flowers per plant in both crops. The increasing shade intensities decreased flower number. The reduction was significantly higher at 1 m and 2 m on either side of the tree as compared to that at 3 m distance from the tree trunk (Table-1). In *V. mungo*, the decline in flower number per plant was 68 per cent and 53 per cent of control (without tree) at 1 m and 3 m distance, respectively from the tree with no crown removal (Table-1), whereas in *P.*

sativum this was only 28 per cent and 13 per cent (Table-1).

The interaction between the shade intensities and distance from the tree trunk significantly influenced leaf area (cm^2, per leaf). The maximum leaf area (38.5 cm^2, per leaf) was observed for control *V. mungo* plants, which decreased with increasing shade intensities. The decrease in leaf area (cf. control) at 3 m distance from the tree trunk was comparatively less than that at 2 and 1 m under all the crown management treatments (Table-1). The leaf area reduction under the shade in *P. sativum* was 10 per cent higher as compared to *V. mungo* (Table-1).

The shade intensities between 47-91 per cent significantly reduced pod number, number of grains per pod and grain yield compared to control during the present study (Table-2). The maximum pod number was found in sole crops (without tree). The pod number in *V. mungo* grown under trees with 75% crown removal was 21.6 at 3 m distance from the tree trunk, which further decreased to 5.0 up to 1 m distance from the trees (Table-2). The values in plants growing under trees with 25 per cent and 50 per cent crown removal were comparatively lower than that under 75 per cent crown removal at all the three distances. The interaction between shade intensities and distance from the tree trunk revealed significant impact on grains per pod. The increase in shade intensities (less crown removal) decreased number of grains per pod in both the crops *per se*. The number of grains per pod was comparatively higher at 3 m distance and 75 per cent crown removal as compared to that at 1 m distance and no crown removal (Table-2). A similar trend with respect to pod number and number of grains per pod was observed in *P. sativum*, so the data have not been included in Table-2.

The grain yield in *V. mungo*, growing beneath *Morus* canopy, was adversely affected by the shade intensities from 47-91 per cent as compared to control (full sun). The maximum grain yield (43.5 g m^{-2}) was recorded in plants without tree. The yield reduced gradually with increasing shade and decreasing distance from the tree trunk (Table-2). All the crown management treatments i.e. 25, 50 and 75 per cent crown removal resulted in a higher yield reduction at 1 m compared to 3 m distance from tree trunk. The net yield reduction (cf. control) under the maximum shade (no crown removal) at 1 m distance was 60.2 per cent; whereas 75% crown removal resulted yield reduction of 5.3 per cent only at 3 m from the tree trunk, compared to open sun. This is significantly lower than that under no crown removal (Table-2). The maximum harvest index (0.28) was observed for the control plants. The plants under trees with 75 per cent crown removal at 3 m distance from the trunk showed higher harvest index (0.26), whereas the minimum (0.24) at 1 m distance and no crown removal. The trend observed was open >75 >50 >25 >0% crown removal (Table-2). The yield was not determined in *P. sativum* because the pod filling was adversely affected due to no rains and pods with shrinkled seeds were produced.

The changed light environment (different shade intensities) during this study influenced photosynthetic rate, amount of water transpired and conversion efficiency in both *V. mungo* and *P. sativum* (Table -3). The photosynthetic rate was maximum in control plants of both the crops e.g. 27.44 and 15.02 m mol m^{-2} s^{-1} in *V. mungo* and *P. sativum*, respectively and decreased with the increasing shade intensities. The photosynthetic rate was minimum at 1 m distance from the trees with no crown removal (Table-3). A decline in photosynthetic rate was more at 1 m distance as compared to 3 m distance on both sides of the trees. In *V. mungo* and *P. sativum*, the photosynthetic rate at 3 m distance under 75 per cent crown removal was 21.57 and 13.66 m mol m^{-2} s^{-1}, respectively, whereas the rate at 1 m distance with no crown removal was 2.60 and 2.75 m mol m^{-2} s^{-1}, respectively (Table -3).

The effect of interaction between shade intensities and distances from the tree trunk was significant on the transpiration rate in both the crops. The maximum transpiration rate in *V. mungo* was recorded for control plants (3.10 m mol m^{-2} s^{-1}),

Table-1: Effect of crown management on growth parameters in *Vigna mungo* and *Pisum sativum* (55 days after sowing) with respect to distance from the tree trunk (D_1 (1 m), D_2 (2 m) and D_3 (3 m) are distances away from tree trunk)

Crown removal (T)	*Vigna mungo*												*Pisum sativum*											
	Plant height (cm)				Number of flowers per plant				Leaf area per leaf (cm^2)				Plant height (cm)				Number of flowers per plant				Leaf area per leaf (cm^2)			
	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
0%	34.0	36.4	39.0	36.5	11.3	14.6	16.7	14.2	23.3	33.2	35.5	30.7	43.2	44.6	46.8	44.9	12.8	13.8	15.4	14.0	2.7	3.1	4.1	3.3
25%	34.2	41.5	48.8	41.5	14.8	16.7	20.7	17.4	29.0	33.6	36.0	32.9	44.1	45.3	47.2	45.5	13.0	14.3	15.4	14.2	3.0	3.1	4.4	3.5
50%	44.0	44.8	47.0	45.3	21.3	24.2	27.7	24.4	29.5	33.4	36.3	33.1	43.9	45.0	46.9	45.2	13.9	15.4	16.0	15.1	3.0	3.1	4.7	3.6
75%	47.4	49.1	52.3	49.6	26.8	29.5	32.1	29.4	31.5	33.0	36.8	33.8	44.4	46.2	47.7	46.1	14.9	16.0	16.6	15.8	3.3	4.6	5.3	4.4
Open	55.6	55.6	55.6	55.6	35.9	35.9	35.9	35.9	38.5	38.5	38.5	38.5	52.5	52.5	52.5	52.5	17.8	17.8	17.8	17.8	5.3	5.3	5.3	5.3
Mean	43.0	45.5	48.5		22.0	24.2	26.6		30.4	34.3	36.6		45.6	46.7	48.2		14.4	15.5	16.2		3.5	3.8	4.8	

LSD at 5%

T	1.55	0.46	0.70	0.63	0.46	0.17
D	0.98	0.35	0.54	0.34	0.36	0.13
TxD	2.19	0.79	1.23	1.94	0.81	0.29

which was followed by plants under 75% crown removal at 3 m distance (2.55 m mol m^{-2} s^{-1}). The minimum transpiration rate was found at 1-m distance under no crown removal (Table 3). A similar trend was observed in *P. sativum*, where the maximum transpiration in control (2.30-mmol m^{-2} s^{-1}) declined significantly under the trees with no crown removal at 1-m distance (1.86 m mol m^{-2} s^{-1}).

The increasing shade intensities resulted in decreased conversion efficiency in both the field crops. The maximum conversion efficiency in control plants of *V. mungo* (1.18%) and *P. sativum* (0.75%) was followed by plants under 75% crown removal at 3 m distance from the tree trunk i.e. 0.95% in *V. mungo* and 0.72% in *P. sativum*. The minimum values were observed in the plants under no crown removal at 1 m distance from the tree trunk, where values were 0.30% and 0.38%, respectively (Table-3). The conversion efficiency was more at 3-m distance, which declined with decrease in distance up to 1 m from tree trunk.

Fig.2 indicates influence of canopy management treatments on the ability of leaf and branch wood biomass production. The biomass production was lower when 50% or 75% crown was removed relative to 25% or no crown removal. Leaf as well as branch wood biomass production was maximum in *Morus* trees with no crown removal.

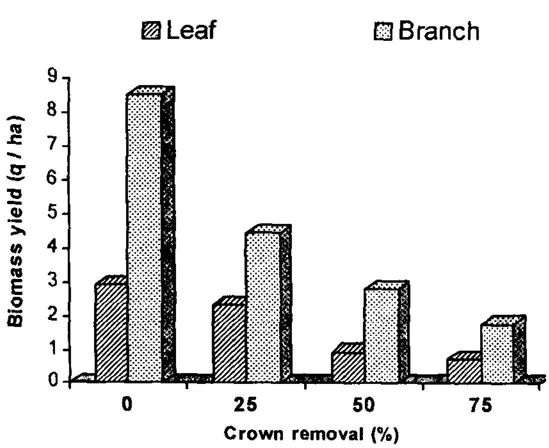

Fig. 2. Canopy management effect on biomass production.

DISCUSSION

During the present investigation it was observed that regulation of shade intensities achieved through the crown management in *Morus alba* based agroforestry system, significantly influenced various attributes related to the performance of field crops i.e. *V mungo* and *Pisum sativum*. The crop growth (plant height, flower number and leaf area) was observed to be minimum in close vicinity of *Morus* trees, but improved with the increase in distance (up to 3 m) from the tree trunk. This reflects more adverse effects of higher shade intensities immediately beneath tree canopies. The light stress on account of the presence of managed as well as unmanaged tree crown caused a significant reduction in yield related parameters in both the crops compared to control (full sun). Comparatively higher values for yield attributes (i.e. pod number, grain per pod, yield, harvest index) were recorded in the open (without tree) probably due to the uninterrupted solar radiation available in the open plots. However, in tree-crop combinations, which included different levels of shade intensities, imposed through crown management, higher values were recorded in 75% crown removal and least value in no crown removal i.e. with increase in shade intensities there was a subsequent decrease in the yield related parameters (Table-2). The findings of the present study suggest that increase in crop yield with increase in distance up to 3 m from the tree trunk and decrease with decrease in distances is the result of less availability of photosynthetically active radiation beneath tree canopy. The differential reduction in growth and yield related parameters may be attributed to the fact that trees with the maximum shade (large canopies) restrict the amount of photosynthetically active radiation (PAR) reaching to crops, which in turn reduces photosynthesis. This is further supported by the data obtained for photosynthesis during the present study (Table-3), where a significantly higher rate of photosynthesis was observed in plants growing under less shade (more crown removal) and at greater distance from the tree trunk. The possibility that field crops may benefit microclimatic improvement due to the

Table-2: Effect of crown management on yield related parameters in *Vigna mungo* at harvest with respect to distance of planting to the tree trunk. (D_1 (1 m), D_2 (2 m) and D_3 (3 m) are distances away from tree trunk).

Crown removal (T)	Number of pods per plant				Number of grains per pod				Grain yield (g m^{-2})				Harvest Index			
	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
0%	5.0	8.3	10.9	8.1	5.8	6.0	6.2	6.0	17.3	22.9	35.1	25.1	0.22	0.23	0.25	0.23
25%	10.2	12.9	13.7	12.3	6.7	6.9	7.4	6.9	20.8	30.5	38.5	29.9	0.22	0.23	0.25	0.23
50%	14.8	15.5	17.1	15.8	6.6	7.1	7.6	7.1	25.4	34.9	40.9	33.7	0.23	0.23	0.26	0.24
75%	19.0	21.9	21.6	20.9	7.5	7.8	8.2	7.8	26.7	38.4	41.2	35.4	0.23	0.25	0.26	0.25
Open	24.4	24.4	24.4	24.4	8.2	8.2	8.2	8.2	43.5	43.5	43.5	43.5	0.28	0.28	0.28	0.28
Mean	14.7	16.6	17.5		6.9	7.2	7.5		26.7	34.0	39.8		0.24	0.24	0.26	

LSD at 5%

T	0.13	0.21	1.0	0.004
D	0.13	0.13	0.8	0.003
TxD	0.31	0.36	2.0	0.006

Harvest index was calculated by dividing total grain yield by total straw + grain yield.

Table-3: Crown management effect on physiological attributes in *Vigna mungo* and *Pisum sativum* at flower initiation stage (D_1 (1 m), D_2 (2 m) and D_3 (3 m) are distances away from tree trunk)

Crown removal (T)	*Vigna mungo*												*Pisum sativum*											
	Photosynthesis (μ mol $m^{-2}s^{-1}$)				Amount of water transpired (m mol $m^{-2}s^{-1}$)				Conversion efficiency (%)				Photosynthesis (μ mol $m^{-2}s^{-1}$)				Amount of water transpired (m mol $m^{-2}s^{-1}$)				Conversion efficiency (%)			
	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
0%	2.60	4.55	6.31	4.49	0.90	1.21	1.33	1.15	0.30	0.39	0.39	0.36	2.75	4.11	5.87	4.24	1.86	1.98	2.11	1.98	0.38	0.41	0.47	0.42
25%	4.57	8.57	11.46	8.20	0.91	1.15	1.55	1.20	0.56	0.56	0.57	0.56	4.05	5.32	6.87	5.41	1.90	2.00	2.10	2.00	0.44	0.56	0.56	0.52
50%	5.86	10.10	17.46	11.14	0.95	1.34	1.45	1.25	0.58	0.62	0.72	0.64	4.34	5.82	8.49	6.22	1.91	2.10	2.19	2.07	0.43	0.47	0.61	0.50
75%	6.40	13.52	21.57	13.83	1.30	1.80	2.55	1.88	0.59	0.76	0.95	0.77	5.21	6.84	13.66	8.57	2.01	2.10	2.20	2.11	0.45	0.51	0.72	0.56
Open	27.44	27.44	27.44	27.44	3.10	3.10	3.10	3.10	1.18	1.18	1.18	1.18	15.02	15.02	15.02	15.02	2.30	2.30	2.30	2.30	0.75	0.75	0.75	0.75
Mean	9.37	12.84	16.85		1.43	1.72	2.00		0.64	0.70	0.76		6.27	7.42	9.98		2.00	2.10	2.18		0.49	0.54	0.62	

LSD at 5%

T	0.52	0.03	0.02	0.23	0.03	0.05
D	0.40	0.02	0.02	0.18	0.02	0.04
TxD	0.89	0.05	0.05	0.41	0.05	0.09

presence of tree canopy was not apparent in the present study. The results of the present investigation are in accordance with the findings of many other workers who have earlier reported significant reduction in yield of many crops (Eriksen and Whitney, 1984; Nkrumah *et al.*, 1986; Ong et al., 1991 and Khybri *et al.*, 1992; Thakur and Dutt, 2003).

The performance and aggressiveness of crop components in any Agroforestry system depend on the maintenance of higher physiological status and efficient use of resources to their advantage. So, any alteration in the normal functioning of the physiological processes, especially anabolic will have a direct bearing on the production potential of crop. The shade resulting from managed and unmanaged *Morus* canopies during the present study has adversely affected the pace of important physiological processes like photosynthesis, amount of water transpired, conversion efficiency etc. It was found that higher shade intensities had more adverse effect on these parameters, which in turn regulate growth and yield related processes. Photosynthesis is the most important physiological process that decides biological yield. Transpiration at any time reflects internal water status as well as normal functioning of stomatal apparatus (Thakur *et al.*, 2000; Thakur and Kaur, 2001). The conversion efficiency, indeed, indicates the cumulative effects on the ability of field crops to convert intercepted solar radiation into biological yield.

On the basis of present study, it can be concluded that *Morus* trees causing shade intensities between 60-91 per cent (treatments, i to iii) affect the performance of *V. mungo* (syn. *Phaseolus mungo*) and *P. sativum* more adversely compared to 47 per cent shade caused by 75 per cent crown removal. Unmanaged canopy of 5- year old *Morus* trees, resulting 91 per cent shade, causes an overall yield reduction of 42 per cent up to 3 m distance from the tree trunk, whereas 75 per cent crown removal causes only 18 per cent yield reduction. Therefore, it can be recommended that out of the four canopy management options (0, 25, 50 and 75% crown removal), tried during the present study; 75% crown removal may be adopted as an acceptable crown management practice for better resource sharing and least adverse effects on the growth and yield of *V. mungo* and *P. sativum* under rainfed conditions.

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