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INFLUENCE OF NITROGEN AND PHOSPHORUS LEVELS ON PHYSIOLOGICAL PARAMETERS AND ECONOMICS OF SORGHUM IN *EUCALYPTUS TERETICORNIS* BASED AGRISILVICULTURE SYSTEM

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ABSTRACT

A field experiment was conducted on sandy loam soil to study the response of various fertilizer levels on *Sorghum bicolor* in 5-6 year old *Eucalyptus tereticornis* Sm. based agrisilviculture system. The crop growth rate increased significantly with increase in fertilizer levels up to 125 per cent of recommended dose of fertilizer at all crop growth stages in both the systems. On the basis of average of two crop seasons 36.8 and 36.7 per cent less photosynthesis, 47.5 and 46.3 per cent less transpiration, and 23.0 and 23.1 per cent less stomatal conductance at 40 days after sowing and at harvest, respectively, were recorded under eucalyptus sown sorghum than sole sorghum. Higher returns and cost/benefit ratio were recorded in agrisilviculture system than sole sorghum.

Key words : *Eucalyptus tereticornis*, *Sorghum bicolor*, stomatal conductance, photosynthesis, transpiration

Tree cover all over the world and more so in India has been reduced by alarming proportions, sites have been denuded and water and wind erosion have affected vast stretches of land. The importance of agroforestry for food, fuel, fodder, fruits, fertilizer, timber, etc. and also in conservation of natural resources has been well recognized. Globally 46 per cent of agricultural land (over one billion hectares) has more than 10 per cent tree cover, while 17 per cent of farming land has more 30 per cent tree cover. This land with more than 10 per cent tree cover is occupied by 31 per cent of the people living in agricultural land (558 million) as reported by Zomer *et al*. (2009). Eucalyptus has more than 600 species, among which *Eucalyptus tereticornis* Smith are cultivated more among the farming communities in India. Eucalyptus is used as timber, poles, firewood, pulping for paper, rayon and for making charcoal. The leaves of several species of eucalyptus are distilled for oil. Yield of honey can be increased in the neighborhoods of eucalyptus plantation. In north India, there is large scale afforestation of eucalyptus along the canals, roadsides and farmers' fields on field bunds as well as in blocks. Block plantation of eucalyptus has adverse effect on associated crops because being evergreen in nature, continues to compete for light, moisture and nutrient throughout the year and is also allelopathic in nature. Fodder sorghum (*Sorghum bicolor*) is a premier crop of semi-arid tropics and a major staple food in several parts of the world. Among the rainy season forages, sorghum is an important fodder crop as it can be fed as green fodder or converted into high quality silage for use in lean period. The strategy of fertilizer management is one of the important agronomic techniques for enhancing productivity and nitrogen and phosphorus play a pivotal role in the nourishment of sorghum. The different authors reported variable performance of fertilizer requirement of crops in different agrisilviculture systems (Osman *et al*., 1998;

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Subrahmanyam *et al*., 2001). The present study, therefore, was carried out to evaluate the optimum fertilizer requirement of sorghum in eucalyptus based agrisilviculture system and influence of fertilizer levels on physiological and economics of sorghum under *E. tereticornis* based agrisilviculture system vis-à-vis sole crop.

MATERIALS AND METHODS

The present investigation was carried out at the Research Area of Agroforestry Department, CCS Haryana Agricultural University, Hisar ($20^0 10^{/}$ N, $75^0 46^{/}$E, 215 m above mean sea level), situated in the arid region of north-western India. The climate is subtropical-monsoonic with an average rainfall of 350-400 mm (70-80% of which occurs during July to September). The soil of the experimental fields was sandy loam in texture and available N, P and K were in low, medium and high range, respectively, under both the agrisilviculture and sole cropping system. The total rainfall of 127 and 386 mm was received in entire growth period of crop during 2004 and 2005, respectively.

Sorghum was grown in a plot having an area of 6 x 4 m during rainy seasons of 2004 and 2005 in between the rows of *E. tereticornis* (planted in July, 1999 at a spacing of 6 x 2 m) and as sole crop (without eucalyptus) in the field adjacent to eucalyptus plantation. The eucalyptus tree height was 12.38 and 14.90 m, girth was 40.20 and 45.18 cm and canopy width 3.98 and 4.09 m, respectively, during July, 2004 and July, 2005. The experiment consisting of four fertilizer levels viz. F_0 (control i. e. without fertilizer), F_1 (75% of recommended dose of fertilizer i. e. 56.25 kg N+11.25 kg P_2O_5/ha), F_2 (100% of recommended dose of fertilizer i. e. 75 kg N+15 kg P_2O_5/ha) and F_3 (125% of recommended dose of fertilizer i. e. 93.75 kg+18.75 kg P_2O_5/ha), was laid out in randomized block design with four replications with eucalyptus and as sole crop. The recommended dose of fertilizer for sorghum is 75 kg N+15 kg P_2O_5/ha. Before the application of pre-sowing irrigation field was ploughed twice. After the application of pre-sowing irrigation two ploughings with disc harrow and one with cultivar followed by planking were given to prepare a good seed bed for sowing of sorghum. Half dose of nitrogen was applied at sowing time and remaining half after one month of sowing as per treatments and the whole phosphorus was applied at the time of sowing through urea (46%) and single super phosphate (16%), respectively, as basal application.

Sorghum (cv. H. C.-171) was sown in north-south direction on 6 July 2004 and 12 July 2005 by hand plough at a row spacing of 25 cm, using seed rate of 50 kg seed/ha in both the systems. The growth parameters of sorghum were recorded at various stages. The physiological parameters of sorghum were recorded at various growth stages in both the systems. The crop growth and relative growth rates were measured at 21-40, 41-60, 61-72 and 21-40, 41-60, 61-75 stages during 2004 and 2005, respectively, and were calculated by using the following formula :

$$CGR = \frac{w_2 - w_1}{t_2 - t_1}$$

$$RGR = \frac{1}{w_1} \times \frac{w_2 - w_1}{t_2 - t_1}$$

Where, w_2 and w_1 = Total dry matter at successive stages
t_2 and t_1=Time interval

Photosynthesis, transpiration and stomatal conductance were measured at 40 days after sowing (DAS) and at harvest of sorghum with the help of portable steady photosynthetic apparatus (IRGA, CIRAS-1, PP system, U. K.). Photosynthesis, transpiration and stomatal conductance of fully developed leaves were recorded on clear sky day during 1100-1300 h of day. Photosynthetic pigments were estimated according to the Hiscox and Isractstman (1979) using dimethyl sulphoxide (DMSO).

Cost of cultivation and gross income of various treatments were calculated on the basis of approved market rates for inputs and outputs. Net returns (Rs./ha) were worked out by subtracting the total cost of cultivation of each treatment from the gross income of the respective treatment. The cost and return of eucalyptus based agrisilviculture system comprising crop with life cycle of one growing season and eucalyptus with 8.5 years was computed for two experimental years on per hectare basis. The expected establishment and maintenance cost of eucalyptus was computed from the first year up to 8.5 years rotation of tree. The expected girth (60 cm) of the eucalyptus after 8.5 years was calculated on the basis of annual girth increment of 5 cm obtained during the course of experiment. The numbers of trees to be harvested (708) were calculated after taking into account 15 per cent mortality. The expected return from eucalyptus trees/ha was computed on the basis of market rates per tree (Rs. 651) prevailing during December 2005 and assuming the same rates after 8.5 years. Cost/benefit ratio was computed by dividing discounted return by discounted cost. The experimental data collected during the course of investigation were subjected to statistical analysis by "Analysis of variance" technique by Fisher (1948) and Cochran and Cox (1959). Critical difference (CD at 5%) was worked out for differentiating the treatment effects from those of chance effects.

RESULTS AND DISCUSSION

Crop Growth Rate and Relative Growth Rate

The maximum value of crop growth rate (CGR) was recorded at 21-40 days interval during both the years and in both the systems, except during 2004, maximum CGR in sole sorghum was recorded at 41-60 days interval. The crop growth rate increased significantly with increase in fertilizer levels up to 125 per cent of recommended dose of fertilizer at all the intervals in both the systems (Fig. 1). The maximum relative growth rate (RGR) in sorghum was recorded at 21-40 days interval and then decreased up to harvest in both the systems. In sorghum at 21-40 days interval, RGR increased significantly with increase in fertilizer levels up to 125 per cent recommended dose of fertilizer in both the systems (Fig. 2). At 41-60 days interval, RGR significantly increased with increasing fertilizer levels up to recommended dose of fertilizer in both the systems during 2005, whereas during 2004 it increased significantly only upto 75 and 100 percent of recommended dose of fertilizer in sole sorghum and in agrisilviculture system, respectively. At harvest, different fertilizer levels had no effect on RGR during both the years and in both the systems. Ram and Singh (2003) reported that nitrogen application @ 80 kg/ha significantly increased the crop growth rate and relative growth rate as compared to control and 40 kg N/ha in sorghum. The beneficial effect increased with increase in fertilizer levels. At low levels of nitrogen, plants might have not received sufficient nitrogen, which ultimately resulted in stunted growth. At higher levels of N, crop absorbed sufficient amount of N resulting in better growth. With adequate supply of nitrogen and phosphorus, crop synthesized more carbohydrates which were rapidly converted into proteins. These proteins, in turn, are required for the formation of protoplasm resulting in more cell division and cell enlargement and favourable improvement in the growth of crop. The reduced CGR and RGR in eucalyptus sown sorghum as compared to sole sorghum were mainly due to the reduction in

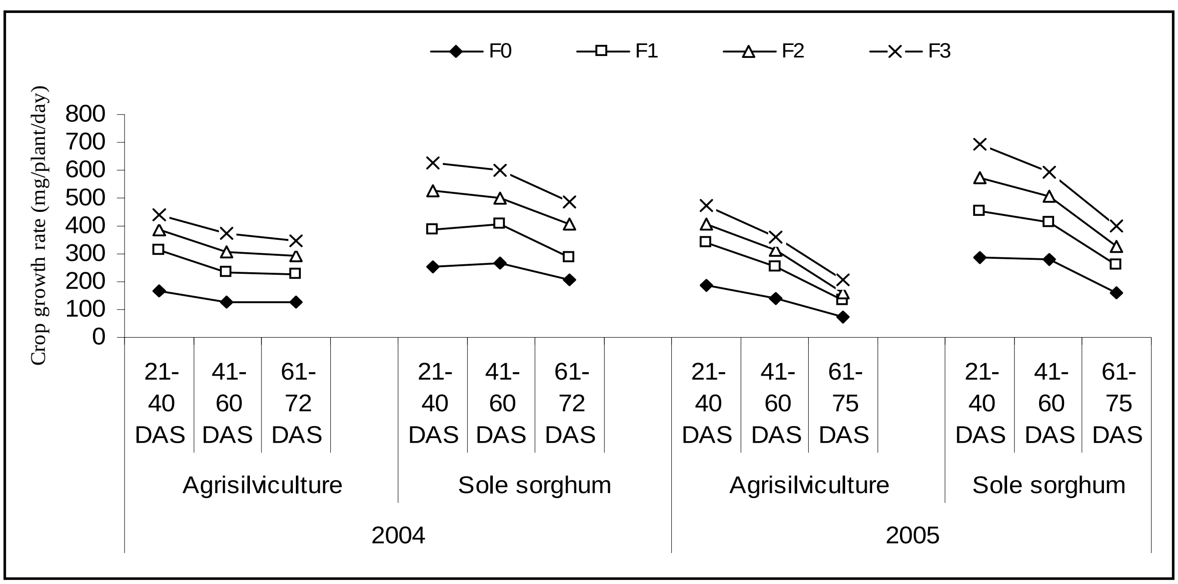

Fig. 1. Effect of fertilizer levels on crop growth rate (mg/plant/day) of sorghum in agrisilviculture and sole sorghum (Pooled data of 2004 and 2005).

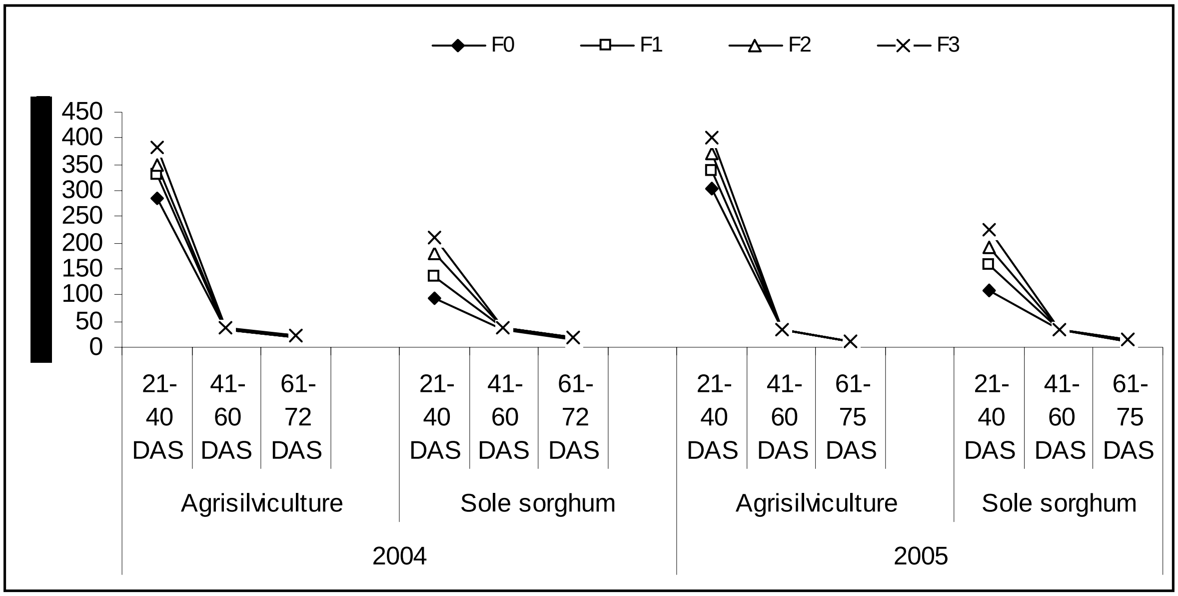

Fig. 2. Effect of fertilizer levels on relative growth rate (mg/plant/day) of sorghum in agrisilviculture and sole sorghum (Pooled data of 2004 and 2005).

incidental solar radiation. The mean per cent light available to crop under agroforestry was only 15.7 and 15.1 per cent at 40 and 60 DAS, respectively as compared to open area.

Photosynthetic Pigments, Photosynthesis, Transpiration and Stomatal Conductance

The total chlorophyll and caroteniod content increased with the advancement of crop age up to harvest during both the years and in both the systems. In agrisilviculture system, at 20, 40 and 60 DAS total chlorophyll increased significantly with increase in fertilizer levels up to 125 per cent of recommended dose of fertilizer during both the years except that during 2004 at 40 DAS the differences between 75 and 100 per cent of recommended doses of fertilizer were not significant. At harvest, total chlorophyll content increased significantly with increase in fertilizer levels up to recommended dose of fertilizer during both the years (Fig. 3). In sole sorghum, during 2004 total chlorophyll at 20 DAS and at harvest significantly increased up to recommended dose of fertilizer and at 40 and 60 DAS, it increased significantly up to 125 per cent of recommended dose of fertilizer. During 2005, the total chlorophyll content increased significantly with increase in fertilizer levels up to 125 per cent of recommended dose of fertilizer except at 20 DAS, where it increased significantly only up to recommended dose of fertilizer. Patidar and Mali (2004) reported that application of 100 per cent recommended dose of fertilizer significantly increased chlorophyll content in sorghum as compared to lower levels. Caroteniod content of sorghum intercropped with eucalyptus increased significantly up to recommended dose of fertilizer at 20 DAS and at harvest and at 40 and 60 DAS, it increased significantly up to 125 per cent of recommended dose of fertilizer during both the years. In sole sorghum, caroteniod content increased significantly with increase in fertilizer levels up to 125 per cent of recommended dose of fertilizer, however, at 20 DAS, it increased significantly up to recommended dose of fertilizer during both the years. Total chlorophyll and caroteniod content was less in agrisilviculture system as compared to sole sorghum.

The rate of photosynthesis, transpiration and stomatal conductance increased significantly with increase in fertilizer levels up to recommended dose of fertilizer at 40 DAS of sorghum and at harvest in both the systems (Fig. 4). The positive response of these physiological characters to fertilizer particularly nitrogen application was due to its favourable effect on cell enlargement resulting in production of larger leaves which increased the photosynthetic area of plant canopy. The rate of photosynthesis, transpiration and stomatal conductance was slightly higher at harvest as compared to 40 DAS of sorghum during both the years and in

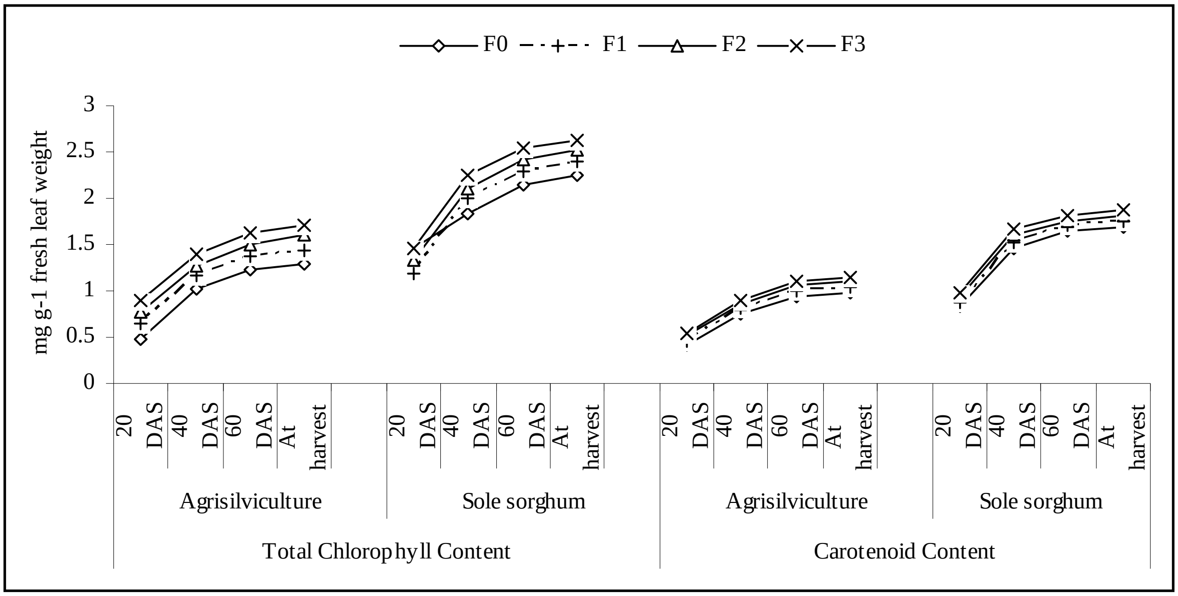

Fig. 3. Effect of fertilizer levels on total chlorophyll content (mg/g fresh leaf weight) and carotenoid content (mg/g fresh leaf weight) of sorghum in agrisilviculture and sole sorghum (Pooled data of 2004 and 2005).

both the systems. Photosynthesis, transpiration and stomatal conductance were more in the sole sorghum as compared to the agrisilviculture system at both the stages of crop growth (40 DAS and at harvest). Roy (2000) also reported that the application of nitrogen and its split application influenced photosynthesis, transpiration, stomatal conductance, chlorophyll 'a', chlorophyll 'b' and carotenoids content in flag leaf of barley. On the basis of average of two crop seasons 36.8 and 36.7 per cent less photosynthesis, 47.5 and 46.3 per cent less transpiration, 23.0 and 23.1 per cent less stomatal conductance at 40 DAS and at harvest, respectively, were recorded under eucalyptus sown sorghum than sole sorghum. Likewise on the basis of average of two years 38 per cent less chlorophyll and 40 per cent less caroteniod contents at harvest in sorghum were recorded under eucalyptus sown sorghum than sole sorghum. Devasagayam and Ebenezar (1996) also reported lower stomatal conductance, transpiration rate and leaf temperature under *E. tereticornis* grown crops (sorghum, cowpea, groundnut and blackgram) than the sole crops. The higher physiological efficiency of sorghum in terms of higher photosynthesis rate, stomatal conductance, transpiration rate and chlorophyll content under open (control) conditions may be attributed mainly to more amount of PAR for longer duration. Based on two years' average, sorghum under eucalyptus got only 15.7 and 15.1 per cent of total light and remaining 84.3 and 84.9 per cent light was reflected at 40 and 60 DAS, respectively.

Green and Dry Fodder Yield

In general, superior growth and yield attributes were recorded during the second year due to higher (386 mm) rainfall than first year (127 mm) of experimentation. Green and dry fodder yield increased significantly up to recommended dose of fertilizer in both the systems and during both the years (Table 1). Better growth with the application of phosphate was probably due to good root ramification and proliferation and absorption of plant food material. Besides this phosphorus is also an essential part of many plant constituents i. e. phospholipids, ATP, etc. A favourable supply of phosphorus might have increased the ATP synthesis in plant and thereby might have accelerated the metabolic processes. The increase in sorghum yield with increase in fertilizer levels was also reported by Ammaji and Suryanarayana (2003), Khalid *et al.* (2003), Angadi *et al*. (2004) and Dhar *et al*. (2005). Poor yield attributes of sorghum resulted in 45 and 42 per cent reduction in green fodder and dry fodder yield, respectively, in sorghum under *E. tereticornis* as compared with sole sorghum. Nandal (1998) reported that plant growth and fodder yield of crops (maize, sorghum, pearlmillet, clusterbean, soybean and cowpea) were lower under the canopy of *Dalbergia sissoo* than in control.

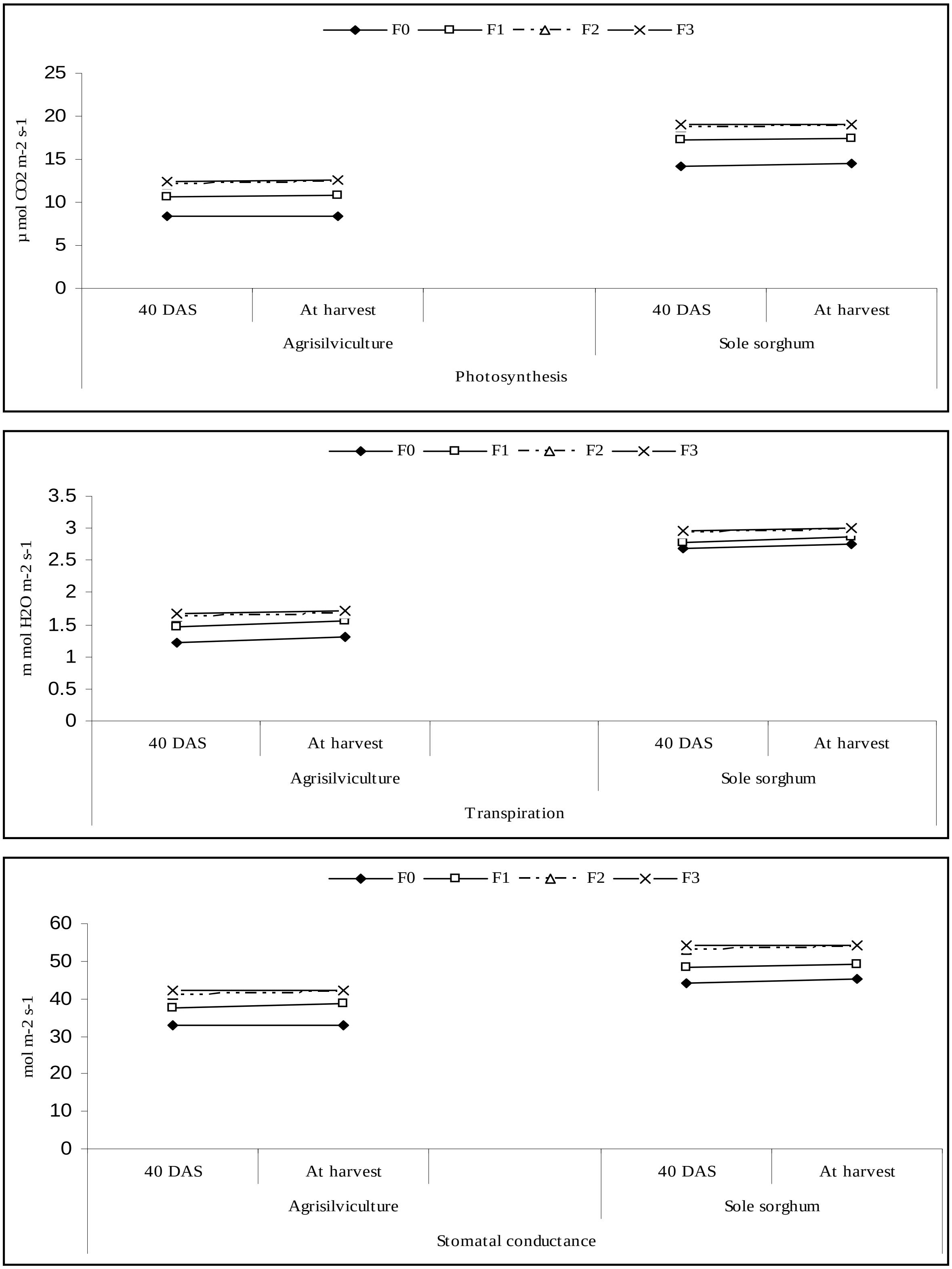

Fig. 4. Effect of fertilizer levels on photosynthesis (µ mol CO_2 m^{-2} s^{-1}), transpiration (m mol H_2O m^{-2} s^{-1}) and stomatal conductance (mol m^{-2} s^{-1}) of sorghum in agrisilviculture and sole sorghum (Pooled data of 2004 and 2005).

TABLE 1

Effect of fertilizer levels on green and dry fodder yield (q/ha) of sorghum in agrisilviculture and as sole sorghum (Pooled data of 2004 and 2005)

Treatments (N, P kg/ha)	Green fodder yield (q/ha)		Dry fodder yield (q/ha)	
	Agrisilviculture	Sole sorghum	Agrisilviculture	Sole sorghum
F_0 (control)	187.5	336.0	28.66	48.65
F_1 (15+30)	231.5	416.5	35.04	59.71
F_2 (20+40)	247.0	455.0	37.14	64.50
F_3 (25+50)	257.0	468.5	38.29	65.75
C. D. (P=0.05)	13.08	26.64	1.61	3.35

TABLE 2

Economics of sorghum grown with *Eucalyptus tereticornis* and as sole crop influenced by various fertilizer levels (Pooled data of 2004 and 2005)

Treatments (N, P kg/ha)	Agrisilviculture				Sole sorghum			
	Gross returns (Rs./ha)	Cost of cultivation (Rs./ha)	Net returns (Rs./ha)	Cost/ benefit ratio	Gross returns (Rs./ha)	Cost of cultivation (Rs./ha)	Net returns (Rs./ha)	Cost/benefit ratio
F_0 (control)	63525	30466	33059	1 : 2.08	16800	12704	4096	1 : 1.32
F_1 (15+30)	65800	31700	34100	1 : 2.07	20825	14202	6623	1 : 1.47
F_2 (20+40)	66575	31990	34585	1 : 2.08	22750	14646	8103	1 : 1.55
F_3 (25+50)	67075	32525	34550	1 : 2.06	23425	15366	8058	1 : 1.53
Mean	65743	31670	34073	1 : 2.07	20949	14229	6720	1 : 1.47

Economics

On the basis of average of two crop seasons, the gross returns increased with increase in fertilizer doses and highest gross returns of Rs. 67075/ha were recorded at 125 per cent recommended dose of fertilizer in eucalyptus based agrisilviculture system (Table 2). In sole sorghum, highest gross returns of Rs. 23425/ha were recorded at 125 per cent recommended fertilizer level, on the basis of two crop seasons. The net returns were higher during 2005 as compared to 2004, in both the systems. Ram and Singh (2001) reported that application of 80 kg N/ha significantly increased the sorghum forage yield and net income compared with the control and 40 kg N/ha. Under both the land use systems, maximum net returns were recorded at recommended fertilizer level during both the years. In agrisilviculture system, maximum cost/benefit ratio was recorded in control and recommended dose of fertilizer level, however, in sole sorghum, maximum cost/benefit ratio was recorded at recommended fertilizer dose during both the years. Kumar *et al.* (2003) also reported almost double net profit from poplar based agroforestry as compared to sole agricultural crops. Kumar (2006) also reported higher net returns from eucalyptus+wheat than wheat alone.

Although all physiological parameters and yield of sorghum in association with eucalyptus were low as compared to sole sorghum, however, after accounting for returns from sale of eucalyptus economic returns in agrisilviculture system were higher than sole sorghum. It may, therefore, be concluded that in eucalyptus based agrisilviculture system, there may be loss in terms of crop yield but the loss is well compensated by the sale of eucalyptus at the end of rotation.

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