Indian J. Plant Physiol., Vol. 8, No. 3 (N.S.) pp. 259-263 (July-Sept., 2003)

VARIATION IN PRODUCTION POTENTIAL AND PHYSIOLOGICAL EFFICIENCY OF DIFFERENT CROPPING SYSTEMS UNDER IRRIGATED CONDITIONS

DEVENDRA SINGH* AND SEWA RAM

Project Directorate for Cropping Systems Research, Modipuram, Meerut (UP) – 250 110

Received on 28 Oct., 2002, Revised on 14 Aug., 2003

SUMMARY

The experiment, consisting of ten cropping systems viz. rice-wheat, rice-berseem, rice-potato-wheat, rice-potato-sunflower, rice-wheat-green gram, sorghum (fodder, F)- wheat, sorghum (F)- toria-wheat, pigeonpea-wheat, maize-wheat and sugarcane ratoon-wheat, was conducted during 2000 (*kharif)* and 2001 (*rabi)* to find out most productive and physiologically efficient cropping system. Data on various physiological parameters revealed that, among all the systems evaluated, rice-potato-wheat was more efficient and productive as it gave highest biomass yield (27.13 t/ha), followed by sorghum (F)- wheat (26.1 t/ha), sorghum (F)- toria - wheat (25.0 t/ha) and sugarcane ratoon-wheat (22.2 t/ha). Rice-berseem, on the other hand, was lowest in terms of biomass potential (17.8 t/ha) and growth rate. This was largely appeared to be associated with leaf area, net assimilation rate (NAR) and relative growth rate (RGR) during flowering. Highest RGR and NAR were recorded in maize, pigeonpea and sorghum, during *kharif,* and in wheat, potato and sunflower, during *rabi.* Variation in biomass productivity among different cropping systems, were more associated with LAI (r = 0.84), RGR (r = 0.73) and NAR (r = 0.35). RGR, on the other hand, appeared to be associated with leaf area (r = 0.52) and NAR (r = 0.56), among different cropping systems. Production potential of different cropping systems, in terms of wheat equivalent yield (WEY), was significantly higher in rice-potato-sunflower (21 t/ha), followed by sugarcane ratoon-wheat (16.5 t/ha) and rice-potato-wheat (15.9 t/ha) than the rice-wheat sequence (9.4 t/ha). On the other hand, wheat equivalent yield was lowest in sorghum (F)- wheat (9.1 t/ha) and maize-wheat (7.9 t/ha). Rice-potato-wheat, rice-potato-sunflower and sugarcane (ratoon)- wheat were more productive and efficient cropping system than others.

Key words : **Biomass, cropping systems, growth analysis parameters, wheat equivalent yield.**

INTRODUCTION

Rice-wheat cropping system which contributes to about 74 per cent of the food grains of the country and occupies about 10.5 m ha, is one of the most predominant cropping systems in Indo-gangetic plains of India (Gangwar *et al.* 1998). This system over exploits the natural resource base and consequently leads to degradation in soil health and fertility and finally decreases yield of both rice and wheat over a longer period of time (Woodhead *et al.* 1994). Intensification of rice-wheat crop rotation leads to reduction in yield of both rice and wheat even with the application of higher dose of fertilizers. It has, therefore, become essential to identify more efficient and productive cropping system than rice-wheat. More profitable and remunerative crops like potato and sunflower are therefore, included in the existing rice-wheat sequence to sustain the productivity of this cropping system. The present study was undertaken to evaluate different cropping systems so as to find out more productive

*Corresponding author: e-mail: dsingh@pdcsr.nic.in

and physiologically efficient cropping system than rice-wheat.

MATERIALS AND METHODS

The filed experiment was conducted during 2000 (*kharif*) and 2001 (*rabi*) at main research farm of Project Directorate for Cropping Systems Research, Modipuram Meerut (UP). The soil of the experimental site was sandy loam, having pH 8.2 and organic carbon 0.38 per cent. It was medium to high in total available N (300 kg/ha) and P(28 kg/ha) and medium in K(167 kg/ha). The treatments comprised ten cropping systems namely rice (*Oryza sativa* cv. Saket-4)-wheat (*Triticum aestivum* L. cv. UP 2338), rice (Saket-4)-berseem (*Trifolium alexandrium* cv Pusa Gaint), rice (Saket-4)-potato (*Solanum tuberosum* cv. Kufri Bahar)-wheat (UP 2338), rice(Saket-4)-potato-(Kufri Bahar)-sunflower (*Helianthus annuus* cv. KBSH-1), rice (Saket-4)-wheat (UP 2338)-greengram (*Phaseolus mungo* cv. K-851), sorghum fodder (*Sorghum bicolor* cv Kanpuri local)-wheat (UP 2338), sorghum fodder (Kanpuri local)-toria (*Brassica campestris var. Toria* cv T-9)-wheat (UP 2338), pigeonpea (*Cajanus cajan* L. cv UPAS-120)-wheat (UP 2338), maize (*Zea mays* L cv. Naveen)-wheat (UP 2338) and sugarcane (*Saccharum officinarum* cv. COS-767) ratoon-wheat (UP 2338). The experiment was laid out in randomised block design (RBD) with four replications. All the crops were grown under normal conditions using recommended package of practices for component crops of the system. Biomass, leaf area and shoot length of various component crops under different systems were recorded at 20 days interval. Analysis of various growth parameters were carried out using the methodology as given by Radford (1967). Crop yields (t/ha) were calculated on the basis of net area harvested under each crop. Wheat equivalent yields (WEY) were calculated for all the cropping sequences to compare the yield potential of different systems following Reddy and Reddi (1995). Net returns were also calculated for each crop sequence, keeping in view the inputs and output received from a particular system. While calculating the cost of cultivation, the rental value of the land has not been taken into account but the inputs given and output received in particular system were considered.

RESULTS AND DISCUSSION

An attempt was made to study the physiological efficiency and productivity of various cropping sequences. The data on biomass, leaf area index (LAI), shoot length, yield and various growth analysis parameters viz. net assimilation rate (NAR), relative growth rate (RGR), leaf area ratio (LAR) and relative shoot growth rate (RSGR) are presented in Table 1, 2 and 3. Data revealed significant variation in biomass, shoot length, leaf area index (LAI), NAR, RGR, LAR, RSGR and yield of component crops, among different cropping systems, in all the treatments. The total biomass productivity and cumulative LAI of all the cropping systems were also worked out (Table 2). Among all the systems evaluated, rice-potato-wheat was more efficient and productive (Table 2) as it gave highest biomass yield (27.12 t/ha), followed by sorghum (F)-wheat (26.1 t/ha), sorghum (F)-toria-wheat (25.0 t/ha), rice-wheat-green gram (24.0 t/ha) and sugarcane (ratoon)-wheat (22.2 t/ha). Rice-berseem, was lowest in terms of biomass potential (17.8 t/h). This appeared to be associated with leaf area, NAR and RGR during flowering (Table 1 and 2). Higher grain yield of wheat (5.5 t/ha) was observed in rice-potato-wheat (Table 2). This was largely due to higher biomass and leaf area index. This could be attributed to higher photosynthetic productivity, owing to higher NAR and RGR. Highest RGR and NAR were recorded in maize, pigeonpea and sorghum during *kharif* and in wheat, potato and sunflower during *rabi* (Table 1). Variations in biomass productivity among different cropping systems were more associated with LAI ($r = 0.84$), RGR ($r = 0.73$) and NAR ($r = 0.35$). RGR, inturn, appeared to be associated with leaf area ($r = 0.52$) and NAR ($r = 0.56$). Sukumaran (1989), Nam *et al.* (1998) and Ali *et al.* (1997) reported similar results in potato, pigeonpea and wheat, respectively.

The economic yield (grain and fodder) of different component crops under various cropping sequence were converted into wheat equivalent yield (WEY) and are presented in Table 3. Significantly higher WEY was recorded in rice-potato-sun-flower (21 t/ha), followed by sugarcane (ratoon)-wheat (16.5 t/ha) and rice-potato-wheat (15.9 t/ha) than the rice-wheat sequence (9.4 t/ha). On the other hand, WEY was lowest in sorghum-wheat (9.1 t/ha) and maize-wheat (7.9 t/ha). The increase in the

Table 1. Growth analysis parameters in different cropping systems (*kharif* 2000 and *rabi* 2001).

Cropping system	RGR ($mg\ g^{-1}day^{-1}$)	NAR ($mg\ dm^{-2}day^{-1}$)	LAR ($dm^2\ g^{-1}$)	RSGR ($mm\ cm^{-1}\ day^{-1}$)	Shoot length (cm)
Rice-wheat					
Rice	32.57	7.38	4.41	0.09	71.48
Wheat	57.19	25.75	2.22	0.18	40.38
Rice-berseem					
Rice	33.28	7.09	4.71	0.09	72.88
Berseem	13.48	10.73	1.34	0.22	48.60
Rice-potato-wheat					
Rice	29.49	5.47	5.38	0.07	74.03
Potato	39.27	42.31	0.94	0.11	74.35
Wheat	78.08	54.30	1.49	0.37	54.40
Rice-potato-sunflower					
Rice	33.10	6.43	5.17	0.09	71.68
Potato	37.87	36.15	1.09	0.02	54.93
Sunflower	39.06	44.61	0.88	0.29	210.10
Rice-wheat-green gram					
Rice	41.27	6.51	6.25	0.02	59.05
Wheat	49.97	25.79	1.97	0.21	41.58
Green gram	20.30	4.32	5.78	0.13	66.90
Sorghum (F)-wheat					
Sorghum (F)	53.37	11.61	4.78	0.24	257.75
Wheat	45.26	19.49	2.34	0.21	41.88
Sorghum-toria-wheat					
Sorghum (F)	51.31	11.53	4.53	0.24	255.25
Toria	-	-	-	-	-
Wheat	66.72	33.60	2.03	0.16	27.80
Pigeonpea-wheat					
Pigeonpea	64.83	12.73	5.29	0.35	112.98
Wheat	49.60	32.75	1.62	0.17	38.40
Maize-wheat					
Maize	80.89	13.14	6.24	0.43	177.80
Wheat	54.77	21.95	2.54	0.22	44.10
Sugarcane ratoon-wheat					
Ratoon	9.26	5.75	3.14	0.09	331.05
Wheat	55.00	24.78	2.27	0.20	34.05
CD (P=0.05), *Kharifl* summer crops	10.77	3.29	0.90	0.07	17.61
CD (P=0.05), *Rabi* crops	12.35	12.40	0.42	0.05	8.86

Table 2. Biomass, leaf area index and cumulative LAI of different component crops of different cropping systems.

Treatment	Biomass (t/ha)				Leaf area index			
	I crop	II crop	III crop	Total	I crop	II crop	III crop	Cumulative
Rice-wheat	9.4	10.6	-	20.0	4.2	4.7	-	8.9
Rice-berseem	8.1	9.7	-	17.8	4.3	1.2	-	5.5
Rice-potato-wheat	7.7	5.1	14.4	27.2	5.0	2.3	4.7	12.9
Rice-potato-sunflower	10.3	5.5	3.7	19.5	4.9	2.9	2.3	10.1
Rice-wheat-green gram	7.6	11.7	4.7	24.0	2.9	4.5	4.9	12.3
Sorghum (F)-wheat	12.7	13.4	-	26.1	6.6	4.5	-	11.1
Sorghum (F)-toria-wheat	12.2	-	12.3	24.5	6.9	4.0	-	10.9
Pigeonpea-wheat	5.1	12.2	-	17.2	2.6	6.9	-	9.5
Maize-wheat	8.7	10.6	-	19.3	5.0	4.2	-	9.2
Sugarcane-ratoon-wheat	-	9.7	12.5	22.2	-	5.9	4.9	10.8
CD (P=0.05)	1.4	1.4	1.4	4.2	0.81	0.81	0.80	2.39

Table 3. Economic yield, wheat equivalent yield, cost of cultivation and net returns under different cropping systems.

Treatment	Yield (t/ha)			Wheat equivalent yield (t/ha)	Cost of cultivation (Rs./ha/anum x 1000)	Net return (Rs./ha/anum x 1000)
	I crop	II crop	III crop			
Rice-wheat	5.1	5.1	-	9.4	31.4	30.9
Rice-berseem	5.2	83.2	-	10.1	32.4	19.7
Rice-potato-wheat	5.1	17.7	5.5	15.9	65.8	35.7
Rice-potato-sunflower	5.0	33.4	2.6	21.0	70.3	53.6
Rice-wheat-green gram	5.2	5.4	1.1	12.7	40.6	41.2
Sorghum (F)-wheat	79.3	5.0	-	9.1	28.0	30.5
Sorghum (F)-toria-wheat	78.7	0.7	4.2	10.2	34.8	30.0
Pigeonpea-wheat	1.9	5.2	-	10.2	26.8	39.8
Maize-wheat	3.0	5.3	-	7.9	26.5	26.7
Sugarcane-ratoon-wheat	-	85.0	4.2	16.5	33.6	40.0
CD (P=0.05)	-	-	-	0.4	-	2.08

Note: The prices of different commodities (Rs./q) are — rice grain 490 and straw 20, wheat grain 580 and straw 110, potato 200, toria grain 1100 and stalks 20, sunflower grain 1155 and stalks 20, pigeonpea grain 1500 and stalks 50, maize grain 500 and stalks 30, berseem and sorghum fodder 30, green gram 1500 and sugarcane 85 and it's top 20.

WEY of the various systems ranged form 107 to 223 per cent over the prevalent rice-wheat system (9.4 t/ha). However, grain yield of wheat (5.5 t/ha) was highest in rice-potato-wheat system than others (Table 3). This was mainly due to better growth (biomass) of wheat owing to better soil health as higher amount of nutrients were applied in short duration potato crop. Such increase in production potential has also been reported by Padhi (1993) in rice-potato-cowpea cropping systems and Yadav and Newaj (1990) in maize-potato-mustard-black gram system. Net returns and cost of cultivation of different cropping systems were also worked out (Table 3). Significantly higher net returns were observed from rice-potato-sunflower (Rs. 53.60 x 1000/ha) followed by rice-wheat-green gram (Rs. 41.20 x 1000/ha), sugarcane ratoon-wheat (Rs. 40.0 x 1000/ha) and rice-potato-wheat (Rs. 35.70 x 1000/ha). Net return from rice-berseem system, on the other hand, was lowest than rice-wheat and other cropping systems. This was largely due to low market price of berseem fodder (Rs. 30.00/q) and additional return from wheat straw in rice-wheat system. In addition to this, the cost of cultivation in rice-berseem system was relatively higher owing to higher number of irrigations and cost of manual cuttings in berseem. All these factors influenced the net return from rice-berseem cropping system (Table 3). This confirms our earlier findings on the productivity potential of different cropping system (Sewa Ram and Singh 2000). Based on these findings it could be concluded that rice-potato-wheat, rice-potato-sunflower and sugarcane (ratoon)-wheat are physiologically more efficient and productive cropping system than others.

REFERENCES

Ali, W., Zadakhan, Shah, P., Ali, H., Ayaz, S. and Malile, S. (1997). Correlation and regression analysis of agronomic parameters with grain yield of wheat. *Sarhad J. Agri.* **13:** 329-332.

Gangwar, K.S., Kaur, J., Prasad, K. and Yadav, R.L. (1998). Rice-wheat cropping sequence. In: R.L. Yadav, Kamta Prasad and A.K. Singh (eds.), Predominant Cropping Systems of India, pp. 11-24. Project Directorate Cropping Systems Research, Modipuram, Meerut, India.

Nam, N.H., Subbarao, G.V., Chauhan, Y.S. and Johanson, C. (1998). Importance of canopy attributes in determining the dry matter accumulation in pigeonpea under contrasting moisture regimes. *Crop Sci.* **38:** 955-961.

Padhi, A.K. (1993). Productivity and economics of rice (*Oryza sativa*) based cropping systems. *Indian J. Agron.* **38:** 351-356.

Radford, P.J. (1967). Growth Analysis Formulae—Their Use and Abuse. *Crop Sci.* **7:** 171-175.

Reddy, T.Y. and Reddi, G.H.S. (1995). Cropping Systems. In: T.Y. Reddy and G.H.S. Reddi (eds.) Principles of Agronomy, pp. 458-479. Kalyani Publishers, New Delhi.

Sukumaran, N.P. (1989). Crop productivity model in potato. In : S.M. Karmakar (ed.), Strategies in Physiological Regulations of Plant Productivity, pp. 198-204. Proc. National Seminar of Indian Soc. Plant Physiology, Bombay.

Sewa Ram and Singh, D. (2002). Potato in rice-wheat system for higher productivity and profitability for Northwestern plains. In: S.M. Paul Khurana, G.S. Sekhawat, S.K. Pandey and B.P. Singh (eds.), Potato, Global Research and Development vol. II, pp. 947-950. Indian Potato Association, Shimla.

Woodhead, T., Huke, R. and Huke, E. (1994). Areas, location and ongoing collaborative research for the rice-wheat systems in Asia. In: R.S. Paroda, T. Woodhead and R.B. Singh (eds.) Sustainability of Rice-Wheat Production System in Asia, pp.68-96. RAPA Publication 1994/11. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Yadav, D.S. and Newaj, R. (1990). Studies on increasing the utilization of natural resources through intensive cropping systems. *Indian J. Agron.* **35:** 50-55.