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RESEARCH ARTICLE

Physiological and biochemical evaluation of varagu with blackgram intercropping competition and yield advantage

■ **K. Ananthi and P. Parasuraman**

SUMMARY

Intercropping increases in productivity per unit of land via better utilisation of resources, minimises the risks, reduces weed competition and stabilizes the yield. Many intercropping systems have proved to be better than sole crops in terms of yield because intercropping makes better use of one or more agricultural resources both in time and in space. The beneficial effect of pulse crops is improving soil health in the form of biological nitrogen fixation, leaf fall, addition of considerable amount of organic matter through root biomass, improving microbial biomass and they keep soil productive and alive by bringing qualitative changes in physical, chemical and biological properties and sustaining productivity. The principal advantage of intercropping system is the more efficient utilization of soil, water, nutrient and increased productivity compared with each sole crop under rainfed and irrigated ecosystem. Choice of ecologically sound crops as millets and adoption of intercropping systems are two of suitable options for maximization of productivity in drylands cropping system due to the reason that competition of plant could be minimized not only by spatial arrangement, but also by combining those crops which have best able to exploit soil nutrients. A field study was scheduled to estimate the impact of intercropping varagu with greengram and blackgram cropping system under rain-fed situation onleaf area, leaf area index, specific leaf weight, crop growth rate, chlorophyll content, no. of tillers per plant and grain yield at Centre of Excellence in Millets, Athiyandal, Tiruvannamalai. It was done in *Kharif*, 2018 and 2019. Randomized Block Design was used to conduct this experiment. It has three replications. The aim of this study was to evaluate and compare varagu with blackgram and greengram inter cropping effects, as well as reveal which intercrops better adopts to rainfed cropping systems using these parameters to improve water use efficiency in the production. Highest returns were obtained from Sole Varagu with blackgram (1:1) due to greater productivity under this treatment with comparable cost of cultivation.

Key Words : Small millets, Intercropping, Specific leaf area, Chlorophyll content, Productivity

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MEMBERS OF THE RESEARCH FORUM

Author to be contacted :
K. Ananthi, Department of Crop Physiology, Agricultural College and Research Institute, Vazhavachanur, **Thiruvannamalai (T.N.) India**
Email : ananthiphd@yahoomail.com

Address of the Co-authors:
P. Parasuraman, Regional Research Station, **Paiyur (T.N.) India**

The main aim of intercropping is to augment the total productivity perunit area and time, besides judiciousand equitable utilization of land resources and farming inputs including labour etc., Intercropping allows effective utilization of growth resources through crop intensification both in space and time dimensions.

The canopies of component crops may occupy different vertical layers with taller component tolerant to strong light and high evaporative demand and the shorter component favouring shade and high relative humidity. Similarly, root systems of component crops may exploit the nutrients in different layers of soil and hence utilize the resources in a better way with much less competition.

The scope for enhancement of productivity under irrigated conditions is limited because of over-exploitation of available resources, but there is ample opportunity for boosting yield in drylands by adopting suitable crops and cropping systems. Choice of ecologically sound crops as millets and adoption of intercropping systems are two of suitable options for maximization of productivity in drylands. Millets are ancient nutri-cereals which can play a crucial role in food as well as nutritional security of the country and can assure agricultural sustainability in drylands under intercropping system. The combination of small millet and legume in intercropping is mostly preferred by the farmers in subsistence farming targeting livelihood security. Intercropping has been reported to enhance soil water conservation and reduce run-of (Sharma *et al*., 2017), increase the use of available soil water (Yang *et al*., 2011 and Hu *et al*., 2017) and improve crop yield for the entire systems and the yield per unit of water supplied (Borghi *et al*., 2013 and Qin *et al*., 2013), as well as the yield of crops grown the following year in the rotation. Intercropping practice could modify the microclimate by reducing light intensity, air temperature, desiccating wind and other climatic components.

Small farmers with less income will highly be in stress conditions due to adverse impacts of climate change (Vermeulen *et al.,* 2012). The demand for food is continuously increasing worldwide due to continuously increasing population. Under the situation, when yield of major cereals are in fluctuating, small millets recorded a steady advancement in output over the last five decades as in 1955-56 yield was 388 kg/ha and in 2013-14 it was 633 kg/ ha (Anbukkani *et al*., 2017). During the period of realizing the impacts of climate change, the so-called ignored millets have acquired gratitude as they necessitate a lesser amount of water and may combat extreme temperatures (Saha *et al.,* 2016 and Bandyopadhyay *et al*., 2017). As C4 plant millets can utilize more CO_2 and thus, assure environmental benefits (Rahaman *et al*., 2016).

Small millets - a group of six crops / minor coarse cereals, namely finger millet *(Eleusine coracana),* little millet (*Panicum miliare*)*,* kodo millet (*Paspalum scrobiculatum*)*,* foxtail millet (*Setariaitalica*)*,* barnyard millet (*Echniocholafrumentacea*) and proso millet (*Panicum miliaceum*), representing the area grown in that order. These crops have traditionally been the indispensable component of dry farming system. Millets possess several morpho-physiological, molecular and biochemical characteristics which confer better tolerance to environmental stresses than major cereals. Primarily, the short lifecycle of millets assists in escaping from stress as they require 12–14 weeks to complete their life-cycle (seed to seed) whereas rice and wheat requires a maximum of 20–24 weeks. However, the prevalence of stress conditions and their consequences are circumvented by several traits such as short stature, small leaf area, thickened cell walls, and the capability to form dense root system. Also, the C4 photosynthetic trait is highly advantageous to millets. If we intercrop millets with any legume crop like varagu with blackgram and varagu with greengram then its uality can be made better due to enhanced protein percentage. Varagu cultivated for forage and grain purpose. It is highly tolerant of heat and water shortage. It is good in producing a lot of grain and shortage; that's why it is most liked by farmers. If we intercrop millet with any legume crop then its quality can be made better.

Liebman and Dyck (1993) indicated that weed population density and biomass production may be markedly reduced using intercropping (spatial diversification). Intercrops may demonstrate weed control advantages over sole crops in two ways. First, greater crop yield and less weed growth may be achieved if intercrops are more effective than sole crops in usurping resources from weeds or by suppressing weed growth through alleopathy. Alternatively, intercrops may provide yield advantages without suppressing weed growth if intercrops use resources that are not exploitable by weeds or convert resources to harvestable material more efficiently than sole crops (Geno and Geno, 2001). Lawson *et al.* (2006) reported that in maize-legume intercropping system, legume crops are generally suppressed by weeds and shade effect of corresponding maize crop which cause difference in photosynthetic efficiency of the two intercropped crops. Intercropping also encourages efficient utilization of the environmental resources (Egbe and Adeyemo, 2007).

Legumes to be very good nitrogen fixers; that's why legumes are considered to be good and if they are grown with non-leguminous crops then it gives good quality grain and forage yield. N fixed by the intercrop of legume may be available to the associated cereal in the current growing season or as a residual N for the benefit of a succeeding cereal crop. Legumes fix atmospheric nitrogen in root nodules and thus, improve the nitrogen status of the soil. It saves upto 25% of recommended level of nitrogen application to the associated cereals when grown as intercrop. The crop residues and root nodules of legumes release nitrogen during decomposition for the use of the succeeding crop. These are also believed to reduce the cost of nitrogen application as they are already fixing nitrogen from atmosphere (Anil *et al*., 1998). It's intercropping with non-leguminous crops not only a reason of increase in production of forage but quality is also enhanced due to high level of protein level then cereals. Cereals are also grown in tropical areas with legumes (Nielsen and Jensen, 2001). This practice is also done in rain fed areas (Age nehu and sinebo, 2006). We get higher yields in intercropping system than sole system (Lithourgidis *et al*., 2006).

Intercropping of compatible plants promotes biodiversity by providing a habitat for a variety of insects and soil organisms that would not be present in a single crop environment. Stable natural systems are typically diverse, containing numerous different kinds of plant species, arthropods, mammals, birds and micro-organisms. As a result, in stable systems, serious pest outbreaks are rare because natural pest control can automatically bring populations back into balance (Altieri, 1995). Therefore, on-farm biodiversity can lead to agro ecosystems capable of maintaining their own soil fertility.

Based on intercropping of Varagu with Blackgram grain yield under irrigated and rainfed condition, intercrop productivity compared to sole crop could be selected for increasing the productivity and net-income to the rainfed growing farmers.

MATERIAL AND METHODS

A field study was scheduled to estimate the impact of intercropping varagu with greengram and blackgram cropping system under rain-fed and irrigated situation at Centre of Excellence in Millets, Athiyandal, Tiruvannamalai. It was done in *Kharif*, 2018 and 2019. Randomized Block Design was used to conduct this experiment. It has three replications. Initial soil samples were collected using a screw auger to a 15 to 20 cm depth. Available soilN, P, and K were analyzed adapting a method outlined by Jackson (1973). The experiment is comprised of 8 treatments given below:

T_1– Sole Varagu (45x10 cm)
T_2– Paired row Varagu (60:30x10 cm)
T_3– Paired row Varagu + Groundnut (1:1)
T_4– Paired row Varagu + Black gram (1:1)
T_5– Paired row Varagu + Green gram (1:1)
T_6– Sole Varagu + Groundnut (1:1)
T_7– Sole Varagu + Black gram (1:1)
T_8– Sole Varagu + Green gram (1:1)

The seed rate for varagu is 10- 12.5 kg/ha, green gram and blackgram for 10 kg/ha is used. Varagu variety CO_3, Blackgram TNAU (Bg) VBN 7, Greengram VBN (Gg) 2 and Groundnut TMV (Gn) 13 were sown in lines. Row spacing was 45x10 cm in Varagu and 30x10 cm for legumes. Available soil nitrogen is 120 kg/ha (low), phosphorous is 35 kg/ha (low) and potassium is 500 kg/ha (High). All agronomic practices are considered as normal for all the treatments except those which were under study.

Specific leaf weight (SLW):

Specific leaf weight (SLW) was calculated by using the formula of Pearce *et al.* (1968) and expressed in mg cm^{-2}.

Crop growth rate (CGR):

The crop growth rate (CGR) was estimated by using the formula of Watson (1956) and expressed in g m^{-2} day^{-1}.

RESULTS AND DISCUSSION

The data presented in Table 1 and 2 proved that intercropping of varagu with blackgram, greengram and groundnut significantly affected the morphological, physiological and yield parameters such as plant height, specific leaf weight, chlorophyll content, relative water content, grain yield and straw yield. Intercropping systems tend to be low input, risk reducing under dry farming situations for crop diversification and fulfilment of subsistence objectives.

Varagu is one of the row crops often selected for intercropping to provide shelter to understory crops because of its wide adaptation over a range of climates. An important strategy for increasing productivity and labour utilization per unit area of available land is to intensify land use. Risk of agronomy failure in multi cropping systems is lower than pure cropping systems. It may be an appropriate growth condition for a species and inappropriate for other species (Eskandari *et al.*, 2009). Intercrops composed of non-synchronous patterns of canopy development and different maturation times can display a greater amount of leaf area over the course

Table 1: Performance of varagu based intercropping system on leaf area (cm^2 $plant^{-1}$), leaf area index, specific leaf weight (mg /cm^2), crop growth rate (g m^{-2} day^{-1}), total chlorophyll content (mg /g), no. of tillers / branches and weed density under rainfed condition

Treatments	Leaf area (cm^2 $plant^{-1}$)		Leaf area index		Specific leaf weight (mg /cm^2)		Crop growth rate (g m^{-2} day^{-1})		Total chlorophyll content (mg /g)		Number of tillers / Branches		Weed density (number/ m^2) on 30 DAS
	Varagu	Intercrops	Varagu	Intercrops	Varagu	Intercrops	Varagu	Intercrops	Varagu	Intercrops	Varagu	Intercrops	
T_1– Sole Varagu (45x10 cm)	519.1	-	1.154	-	10.36	-	0.556	-	2.07	-	13.0	-	55.0
T_2 – Paired row Varagu (60:30x10 cm)	435.0	-	0.967	-	9.89	-	1.068	-	2.04	-	12.7	-	56.3
T_3 – Paired row Varagu + Groundnut (1:1)	401.1	280.9	0.891	0.936	9.57	4.23	1.270	0.984	2.26	2.13	10.0	5.0	60.7
T_4 – Paired row Varagu + Black gram (1:1)	500.3	360.4	1.112	1.201	10.25	12.23	1.050	0.964	2.46	2.25	12.7	4.7	45.0
T_5 – Paired row Varagu + Green gram (1:1)	478.3	828.1	1.063	2.760	9.12	13.12	0.979	1.224	2.30	2.09	11.3	4.3	49.3
T_6 – Sole Varagu + Groundnut (1:1)	436.5	279.3	0.970	0.931	9.71	3.78	1.104	0.854	2.70	1.93	11.0	5.7	42.7
T_7 – Sole Varagu + Black gram (1:1)	528.8	413.4	1.175	1.378	10.56	12.85	1.495	1.027	2.94	2.51	14.3	5.3	35.0
T_8 – Sole Varagu + Green gram(1:1)	511.1	859.5	1.136	2.865	10.42	11.21	1.074	1.134	2.88	2.46	13.0	4.7	37.0
S.E.±	5.6	6.1	0.05	0.05	0.17	0.18	0.12	0.043	0.07	0.04	0.77	0.13	0.8
C.D. (P=0.05)	12.2	13.8	0.11	0.10	0.49	0.51	0.29	0.093	0.15	0.09	1.66	0.28	1.8

Table 2 : Performance of varagu based intercropping system on relative water content (%), total dry matter accumulation (g $plant^{-1}$), grain yield (kg/ha) and straw yield (kg/ha) under rainfed condition

Treatments	Relative water content (%)		Total dry matter accumulation (g $plant^{-1}$)		1000 grain weight (g)	Grain yield (kg/ha)		Straw yield (kg/ha)	
	Varagu	Intercrops	Varagu	Intercrops	Varagu	Varagu	Intercrops	Varagu	Intercrops
T_1– Sole Varagu(45x10 cm)	85	-	22.7	-	6.5	1525	-	4605	-
T_2 – Paired row Varagu(60:30x10 cm)	83	-	21.2	-	6.2	1502	-	4458	-
T_3 – Paired row Varagu + Groundnut (1:1)	84	83	21.8	13.9	5.3	1530	837	4458	1028
T_4 – Paired row Varagu + Black gram (1:1)	89	87	22.3	13.9	6.3	1584	668	4739	1126
T_5 – Paired row Varagu + Green gram (1:1)	85	85	22.4	22.2	5.8	1561	634	4678	1601
T_6 – Sole Varagu + Groundnut (1:1)	83	82	23.0	14.1	5.6	1360	1064	4563	1341
T_7 – Sole Varagu + Black gram (1:1)	87	85	24.9	15.6	6.4	1613	1210	4938	2084
T_8 – Sole Varagu + Green gram (1:1)	85	83	24.1	25.3	5.5	1580	1125	4866	2678
S.E.	1.3	0.51	0.58	0.43	6.7	28	18	185	42
C.D. (P=0.05)	2.7	1.15	1.75	1.35	6.2	60	41	400	95

Fig. 2: T_7 – Sole Varagu + Blackgram (1:1)

Fig. 3: T_8 – Sole Varagu + Greengram (1:1)

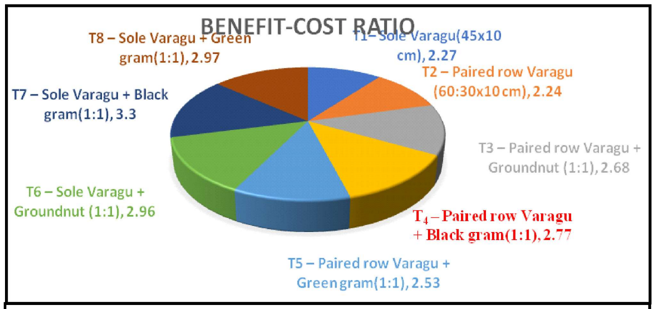

Fig. 1: Performance of varagu based intercropping system on benefit-cost ratio

of the growing season and intercept more total light energy than monocultures. The treatment T_7 – Sole Varagu + Black gram (1:1) intercropping performed well under rain-fed condition with less reduction in leaf area (528.8 cm) and leaf area index (1.175) of varagu. It is followed by treatment T_1– Sole Varagu which shows leaf area (519.1 cm). among the intercropping treatment T_7 – Sole Varagu + Black gram (1:1) gave maximum leaf area and leaf area index when compare to other treatments. In intercropping, it is revealed that due to intercropping of varagu with legumes, treatment T_7 – Sole Varagu + Black gram (1:1), Blackgram performed well under rainfed condition.Leaf area duration represents the functionality of the leaf over its life period. It reflects the duration of the functional leaves. Formation of optimum photosynthetic area and maintaining photosynthetically active leaves for a longer duration especially during the reproductive phase of the crop is essential for increasing the photosynthetic rate, dry matter accumulation and the grain yield (Watson, 1956). The SLW, the parameter indicating the leaf thickness, exhibited an increased thickness from vegetative to grain filling stage. Mohan (2003) reported that the performance of cropping system was enhanced when maize and legumes were intercropped as compared to their sole performance in study. Maize intercropped with legumes in 1:2 row proportion was superior in utilizing natural resources like light and moisture content. Leaf surfaces are the primary photosynthetic organs of the plant, it is sometimes desirable to express growth on a leaf area basis. The varagu plants treatment T_7 [Sole Varagu with Black gram (1:1)] gave highest specific leaf weight (10.56 mg cm^{-2}) under rain-fed condition, followed by T_8 (Sole Varagu with Black gram (1:1)) (10.42 mg cm^{-2}) . Sarika Jena *et al.* (2010) declared that the interception of PAR in sesame canopy was maximum in 4:1 row ratio of sesame + greengram intercropping. Utilisation of light use efficiency was highest in pigenopea + greengram with 1:3 proportion (Udhaya Nandhini and Latha, 2015). The CGR represents accumulated dry matter, which is partitioned among various plant organs. It is also supported by Rao *et al.* (1998) who observed positive correlation between LAI and CGR. As CGR has linear relationship with intercepted irradiance and with maintenance of high LAI, there was higher dry matter accumulation thereby increasing the CGR, ultimately giving higher yield (Shibles and Webber, 1966). The varagu plants treatment T_7 [Sole Varagu with Black gram (1:1)] gave highest crop growth rate (1.495 gm^{-2} day^{-1}), Total chlorophyll content (2.94 mg g^{-1}) and no. of tillers (14) over the other inter cropping. Intercropping is mainly practiced to cover the risk of failure of one of the component crops due to vagaries of weather or pest and disease incidence. Yield advantages in intercropping system are mainly because of differential use of growth resources by component crops. The complementarity will occur when the growth patterns of component crops differ in time. Intercropping of legumes in association with non-legumes helps in utilization of nitrogen being fixed by legumes in the current growing season, but also helps in residual build-up of nutrients in soil (Sharma and Choubey, 1991). Production more in intercropping can be attributed to the higher growth rate, reduction of weeds, reducing the pests and diseases and more effective use of resources due to differences in resource consumption (Eskandari, 2012). Very less number of weed population were identified in Sole Varagu with Black gram (1:1) (35) intercropping followed by, Sole Varagu + Green gram (1:1) (T_8) (37). Lawson *et al.* (2006) reported that in maize-legume intercropping system, legume crops are generally suppressed by weeds and shade effect of corresponding maize crop which cause difference in photosynthetic efficiency of the two intercropped crops. The highest total dry matter accumulation of (24.9 g $plant^{-1}$) was registered under Sole Varaguwith Black gram (1:1) inter cropping system.

Mono crop varagu produced 1525 kg/ha.The treatment T_7 [Sole Varaguwith Black gram (1:1)] under rain-fed condition (1613 kg/ha and 4938 kg/ha) shows the highest value of varagu grain yield and straw yield than the other treatment. The higher magnitude in relative yield loss in groundnut indicated that groundnut faced much more competition in association with the varagu (Banik and Sharma, 2009). Greater crop yield and less weed growth may be achieved if intercrops are more effective than sole crops in usurping resources from weeds or by suppressing weed growth throughalleopathy. Alternatively, intercrops may provide yield advantages without suppressing weed growthif intercrops use resources that are not exploitable by weeds or convert resources to harvestable material more efficiently than sole crops (Geno and Geno, 2001). The benefits of a legume intercrop with respect to nitrogen are direct transfer of nitrogen from the legume to the cereal during the current intercrop and residual effects when the fixed nitrogen becomes available on the sequential crops after the senescence of the legume and the decomposition of residues.

Conclusion:

The scope for enhancement of productivity under rain-fed conditions is limited because of over-exploitation of available resources. Climate change and water scarcity may increase number of extreme weather events in the future agricultural crop production. Innovative and effective approaches are needed to alleviate the challenge. In the present study, we determined the sole varagu with Blackgram intercropping 1:1 ratio, sharing soil water and nutrients between intercrops during the crop growth period. Higher net return is achieved with greater productivity. Highest returns were obtained from Sole Varaguwith Black gram (1:1) due to greater productivity under this treatment with comparable cost of cultivation. Higher gross and net return under intercropping was due to higher total productivity with relative less input investment.

REFERENCES

Agenehu, G., Ghizam, A. and Sinebo, W. (2006). Yield performance and land use efficiency of barley and faba bean mixed cropping in ethopian high lands. *European J. Agronomy*, **25** : 202-207. https://doi.org/10.1016/j.eja.2006.05.002

Altieri, M. A. (1995). *Agroecology: the science of sustainable agriculture*, 2nd Ed. Publisher: Westview Press.

Anbukkani, P., Balaji, S.J. and Nithyashree, M.L. (2017). Production and consumption of minor millets in India-A structural break analysis. *Ann. Agric. Res. New Series,* **38** : 1-8.

Anil, L., Park, J., Phipps, R.H. and Miller, F.A. (1998). Temperate intercropping of cereals for forage: A review of the potential for growth and utilization with particular Reference to the UK. *Grass & Forage Science,* **53**: 301-317.https://doi.org/10.1046/j.1365-2494.1998.00144.

Bandyopadhyay, T., Mehanathan, M. and Prasad, M. (2017). Millets for next generation climate smart agriculture. Front. *Plant Sci.,* **8** : Article No. 1266. doi.org/10.3389/fpls.2017.01266.

Banik, P. and Sharma, R.C. (2009). Yield and resource utilization efficiency in baby corn- Legume-intercropping system in the Eastern Plateau of India. *J.Sustainable Agriculture*, **33** : 379–395.

Borghi, E., Crusciol, C.A.C., Nascente, A.S., Sousa, V.V., Martins, P.O., Mateus, G.P. and Costa, C. (2013). Sorghum grain yield, forage biomass production and revenue as afected by intercropping time. *Eur. J. Agron.,* **51** : 130–139.

Borghi, E., Crusciol, C. A. C., Mateus, G. P., Nascente, A. S. and Martins, P. O. (2013). Intercropping time of corn and palisadegrass or guineagrassafecting grain yield and forage production. *Crop Sci.,* **53** : 629–636.

Egbe, O.M. and Adeyemo, M.O. (2007). Estimation of the effect of intercropped pigeon pea on the yield and yield components of maize in southern Guinea Savannah of Nigeria. *African J. Agric. Res.*, **2** (12): 667-677.

Eskandari, H., Ghanbari, A. and Javanmard, A. (2009). Intercropping of Cereals and Legumes for Forage Production. *Notulae Scientia Biologicae,* **1** (1): 7-13. DOI:10.15835/nsb.1.1.3479.

Eskandari, H. (2012). Yield and quality of forage produced in intercropping of maize (*Zea mays*) with cowpea (*Vigna sinensis*) and mungbean (*Vigna radiate*) as double cropped. *J. Basic & Appl. Scient. Res.,* **2** : 93-97.

Geno, L. and Geno, B. (2001). Polyculture production: Principle, benefits and risk of multiple cropping. A reportforthe rural industry research and development corporation (RIRDC), Publication, No. 01134.

Hu, F., Feng, F., Zhao, C., Chai,Q., Yu, A., Yin, W. and Gan, Y. (2017). Integration of wheat-maize intercropping with conservation practices reduces CO_2 emissions and enhances water use in dry areas. *Soil & Tillage Res.,* **169** : 44–53.

Jackson, M.L. (1973). *Soil chemical analysis.* Prentice Hall of India Inc., New Delhi, pp. 48–97.

Lawson, Y.D.I., Dzomeku, I.K., Asempa, R. and Benson, S. (2006). Weed control in legumes for forage production. *Notulae Scientia Biologicae*, **1** : 7-13.

Liebman, M. and Dyck, E. (1993). Crop rotation and intercropping strategies for for weed management. *Ecological Applications,***3** (1) : 92-122.

Lithourgidis, A.S., Vasilakoglou, I.B., Dhima, K.V., Dordas, C.A. and Yiakoulaki, M.D. (2006) Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. *Field Crops Research,* **99** : 106-113.

Mohan, H.M. (2003). Maize based intercropping studies with grain legumes in Vertisols. M. Sc. (Ag.) Thesis, University of Agricultural Sciences, Dharwad, Karnataka (India).

Nielsen, H. and Jensen, E.S. (2001). Interspecific competition, N use and interference with weeds in pea-barley intercropping. *Field Crops Research,* **70** : 101-109.

Pearce, R.B., Brown, R.H. and Balaster, R.E. (1968). Photosynthesis of alfalfa leaves as influenced by environment. *Crop Sci.,* **36**: 677-680.

Qin, A.Z., Huang, G.B., Chai, Q., Yu, A.Z. and Huang, P. (2013). Grain yield and soil respiratory response to intercropping systems on arid land. *Field Crops Res.,* **144** : 1–10.

Rahaman, H., Ramanathan, V., Nallathambi, J., Duraialagaraja, S. and Muthuranjan, R. (2016). Over-expression of a NAC 67 transcription factor from finger millet (*Eleusine coracana* L.) confers tolerance against salinity and drought stress in rice. *BMC Biotechnol.,* **16** : Article No. 35. doi : 10.1186/s12896-016-0261-1.

Rao, S.S., M.H. Rao, T.K. Krishnan and B.S. Rana. (1998). Characterization of sorghum hybrids and varieties for growth parameters, biomass accumulation and yield potential in rainy season. *Indian. J. Plant. Physiol.,* **3**: 269-273.

Saha, D., Gowda, M. V. C., Arya, L., Verma, M. and Bansal, K. C. (2016). Genetic and genomic resources of small millets. *Crit. Rev. Plant Sci.,* **35** : 56-79.

Sarika Jena, N., Rajib, D., Mazumdar, P., Bandyopadhyay and Chakraborty, P.K. (2010). Pattern of absorption and interception of photosynthetically active radiation in sesamum-greengram intercropping system. *Research J. Agronomy,* **4** : 1-9.

Sharma, N. K., Singh, R.J., Mandal, D. and Kumar, A. (2017). Increasing farmer's income and reducing soil erosion using intercropping in rainfed maize-wheat rotation of Himalaya, India. *Agriculture, Ecosystems & Environment,* **247** : 43–53.

Sharma, R.S. and Choubey, S.D. (1991). Effect of maize legume intercropping systems on nitrogen economy and nutrient status of soil. *Indian Journal of Agronomy,* **36** : 60-63.

Shibles, R.M. and Weber, C.R. (1966). Interception of solar radiation and dry matter production by various soybean planting pattern. *Crop Sci.,* **6** : 55-59.

Udhaya Nandhini, D. and Latha, K.R. (2015). Analysis of light transmission ratio and yield advantages of medium duration pigeonpea in relation to intercrop and different plant population. *African Journal of Agricultural Research,***10** (8) : 731-736.

Vermeulen, S. J., Campbell, B. M. and Ingram, J. S. I. (2012).

Climate change and food systems. *Ann. Rev. Environ. Resour.,* **37** : 195-222.

Watson, D.J. (1956). Comparative physiological studies on the growth of field crops. I.Variation in net assimilation rate and leaf area between species and varieties and within and between years. *Ann. Bot.,* **11**: 41-46.

Yang, C., Huang, G., Chai, Q. and Luo, Z. (2011). Water use and yield of wheat/maize intercropping under alternate irrigation in the oasis feld of northwest China. *Field Crops Res.,* **124** : 426–432.