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RELATIVE ADVANTAGES AND ECONOMICS OF MAIZE BASED INTERCROPPING SYSTEMS

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SUMMARY

A field experiment was conducted at CCS HAU, Hisar during *Kharif* season of 2019 in randomized block design, replicated thrice with thirteen treatments to evaluate the maize based intercropping systems taking soybean, urdbean, clusterbean and mungbean as intercrop with planting patterns of maize + intercrop (1:1) and paired row planting of maize (60:105 cm) with two rows of intercrops in between two pairs. It was concluded that among all intercropping systems, paired row planting of maize at 60:105 cm along with two rows of mungbean in between two pairs was recorded with significantly higher Maize Equivalent Yield (5647 kg/ha), Relative Crowding Coefficient for system (3.73), Land Equivalent Ratio (1.29), net return (61335), Benefit cost ratio (2.37) and per day return (Rs.515.4/ha/day) closely followed by maize + mungbean (1:1) in terms of maize equivalent yield and economics. All indices used for evaluation of intercropping systems under study were significantly influenced by intercropping treatments. Maize was recorded with higher competitive ratio and aggresivity values compared to intercrops, which shows the more competitive nature of maize over intercrops. Among intercrops, mungbean and soybean showed higher competitive nature compared to urdbean and cluster bean against maize crop. Hence, for sustenance of our natural resources and relative economic profitability maize growers should go for paired row planting of maize (60:105 cm) along with two rows of mungbean in between two pairs followed by maize + mungbean (1:1) instead of sole planting of maize.

Key words : Aggresivity, benefit cost ratio, cluster bean, competitive ratio, intercropping, land equivalent ratio, maize, mung bean, soybean, urd bean

Maize (*Zea mays* L.) is one of the most important cereal crops of world's Agricultural economy for human consumption and feed for animal. Among the cereal grain crops, maize ranks third in production in world being surpassed only by rice and wheat (Arya *et al.,* 2015). Maize, because of its wider adaptability, is grown under temperate to tropical regions of the world and has multifarious uses as food, feed, fodder and over 35 daily used industrial products like protein foods, glucose powder, starch, alcohol, etc. Besides the grain, stalk serve as a good fodder for cattle and as such called proudly as 'Queen of Cereals' and 'King of Fodder'. Major challenge of agriculture now-a-days is to reconcile increasing food production while lowering environmental pollution (Matson *et al*., 1997; Wittwer *et al*., 2017). Intensive farming clinging mainly to mono cropping contributes much to crop production, but meanwhile leading to high chemical inputs and low biodiversity (Tilman *et al*., 2002; Guo *et al*., 2010; Liu *et al*., 2013) thus decreasing soil health and system productivity. Intercropping of cereal and legume crops helps maintain and improve soil fertility. Intercropping is an ecological planting pattern of growing two or more crops on the same piece of land within the same year to promote their interaction which can use land and environmental resources more efficiently as compared to monoculture, so as to realize sustainable development of agriculture and guarantee food security. Cereals like maize can be used for intercropping with legumes like soybean, cowpea, cluster bean and moong due to their dissimilar growing patterns, morphology, phenology and nutrient

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requirement. Legumes, with their adaptability to different cropping patterns and ability to fix atmospheric N offer minimum competition for N nutrition and greater opportunities to sustain productivity (Sanginga *et al*., 2002). Inclusion of legumes as intercrop, not only provides nitrogen to the base crop but also increases the amount of humus in the soil due to decaying crop remains (Kheroar *et al*., 2013). The principal advantages for farmers to intercrop are flexibility, profit maximization, risk minimization against crop failure, soil conservation and maintenance, weed control, balanced nutrition, labour management and better utilization of farm machinery (Shetty *et al*., 1995). Depending on component crops, yield advantage may vary considerably due to several factors, including differences in plant architecture, rooting patterns, competitive advantages and potential nitrogen fixing capacity of the legume. Hence, the current study was undertaken to determine the optimum density, suitable intercrop and economics of the maize based intercropping system taking different legume crops viz. soybean, urd bean, cluster bean and mung bean as intercrop with planting patterns of maize + intercrop (1:1) and paired row planting of maize (60:105 cm) with two rows of intercrops in between two pairs.

MATERIALS AND METHODS

A field experiment was carried out at Crop Physiology Field Area of CCS Haryana Agricultural University, Hisar, Haryana, India ($29^0 10^{'}$N latitude, $75^0 46^{'}$E longitude and 215.2 M altitude) during *Kharif* season of 2019 in randomized block design, replicated thrice with thirteen treatments to evaluate maize based intercropping systems taking soybean, urdbean, clusterbean and mungbean as intercrop with planting patterns of maize + intercrop (1:1) and paired row planting of maize (60:105 cm) with two rows of intercrops in between two pairs. The soil of the field was sandy loam in texture, slightly alkaline in pH (8.0), low in organic carbon, poor in available nitrogen and medium in available phosphorus and rich in available potassium. Maize variety HQPM-1 was intercropped with cluster bean (HG 2-20), mung bean (MH-421), urd bean (UH-1) and soybean (SL-958) on 13th July, 2019. The crop was raised with standard crop production practices of Maize as recommended by CCS HAU, Hisar. Intercrops were harvested manually followed by cutting of maize crop from ground level and then threshing was done after separating matured cobs. Data pertaining to yield and yield attributes of maize and intercrops were recorded and analyzed statistically. Different competition and yield advantage indices of intercropping were calculated to study the feasibility and economical viability of different intercropping systems as suggested by (Pal *et al.*, 1985, Willey Rao, 1980 and Padhi *et al*., 2010).

RESULTS AND DISCUSSION

Maize seed yield

Intercropping of different crops in maize has significantly reduced the maize seed yield compared (18.2-22.0 percent) to sole maize. Out of intercropping row arrangements studied, planting of maize with intercrop in 1:1 was found with higher seed yield of maize compared to paired row pattern (60:105) with two rows of intercrop in between pairs of maize but differences in seed yield of maize were non-significant. Irrespective of planting geometry, maize intercropped with urd bean or cluster bean recorded higher seed yield compared to soybean and mung bean as intercrop. Among all intercropping systems, maize + urd bean (1:1) was recorded with higher maize seed yield with a significant reduction of 18.2 percent over sole maize and it was closely followed by maize+ cluster bean (1:1). Among various intercropping indices, Aggresivity and Competitive Ratio were positively correlated with maize seed yield with respective "r" values of 0.73 and 0.95, while Relative crowding Coefficient and Area Time Equivalent Ratio were negatively correlated with maize seed yield with "r" values of 0.87 and 0.82, respectively.

Intercrop yield

Among the intercrops tested, higher seed yield was recorded with soybean followed by mung bean. Irrespective of intercrops out of intercropping row arrangements studied, paired row planting of maize at 60:105 cm along with two rows of intercrop in between two pairs was recorded with higher seed yield of intercrop compared to 1:1 planting pattern. Irrespective of planting pattern each intercrop recorded a reduction in their seed yield over sole planting with a reduction range of 50.9-55.6, 72.9-77.9, 73.9-78.7 and 49.8-56.9 percent respectively for soybean, urd bean, cluster bean and mung bean. Among various intercropping indices, Aggresivity, Relative Crowding Coefficient, Competitive Ratio and Area Time Equivalent Ratio

TABLE 1
Intercropping indices to evaluate the Maize based intercropping systems

Treatments	Seed yield (kg/ha)		Land Equivalent Ratio (LER)			Maize equivalent yield (kg/ha)	Aggressivity (A)		RCC			Competitive Ratio		ATER
	Maize	Inter crop	Maize	Inter crop	System		Maize	Inter crop	K_{MI} (maize)	K_{IM} (inter crop)	$K = K_{MI} * K_{IM}$	Maize	Intercrop	
Sole Maize	4190.0	-	-	-	-	4190.0								
Sole Soybean	-	1713.3	-	-	-	3613.3								
Sole Urdbean	-	726.7	-	-	-	2353.5								
Sole Clusterbean	-	910.0	-	-	-	2173.2								
Sole Mungbean	-	1176.5				4716.7								
Maize + Soybean (1:1)	3320.0	760.0	0.80	0.44	1.23	4920.0	0.17	- 0.17	3.87	0.79	3.06	1.79	0.56	1.16
Maize + Urdbean (1+1)	3426.7	160.6	0.82	0.21	1.03	3940.5	0.30	- 0.30	4.53	0.27	1.26	4.00	0.26	0.89
Maize + Clusterbean (1+1)	3410.3	193.3	0.81	0.21	1.03	3870.0	0.30	- 0.30	4.40	0.27	1.22	3.92	0.26	0.91
Maize + Mungbean (1+1)	3350.0	506.7	0.80	0.43	1.23	5376.7	0.18	- 0.18	4.09	0.76	3.18	1.86	0.54	0.99
Paired row maize (60:105 cm) + 2 rows of soybean	3266.5	840.0	0.78	0.49	1.27	5043.3	0.19	- 0.19	3.08	1.15	3.64	1.35	0.74	1.20
Paired row maize (60:105 cm) + 2 rows of Urdbean	3360.2	196.5	0.80	0.28	1.08	3996.2	0.30	- 0.30	3.53	0.46	1.70	2.60	0.40	0.92
Paired row maize (60:105 cm) + 2 rows of Clusterbean	3346.7	236.8	0.80	0.26	1.06	3910.0	0.31	- 0.31	3.42	0.41	1.44	2.63	0.38	0.94
Paired row maize (60:105 cm) + 2 rows of Mungbean	3286.5	590.2	0.79	0.50	1.29	5646.7	0.19	- 0.19	3.13	1.19	3.73	1.33	0.75	1.02
CD at 5%	123.5	-	NS	0.09	0.12	335.8	0.03	0.03	0.55	0.27	1.27	1.00	0.12	0.09
SEm+	40.8	-	0.01	0.03	0.04	114.4	0.01	0.01	0.18	0.08	0.41	0.32	0.03	0.03

were positively correlated with intercrop seed yield with respective "r" values of 0.92, 0.91, 0.88 and 0.97.

Maize Equivalent Yield (MEY)

Intercropping of maize with different crops affected maize equivalent yield significantly compared to sole maize. Among intercrops, mung bean followed by soybean recorded significantly higher MEY under sole as well as intercropping systems, which may be due to it's higher market price and yield obtained compared to other crops. Irrespective of intercrops out of the planting geometries tested, paired row planting of maize at 60:105 cm along with two rows of intercrop in between two pairs was recorded with significantly higher MEY compared to 1:1 planting pattern. Among all intercropping systems, paired row planting of maize at 60:105 cm along with two rows of mung bean in between two pairs was recorded with significantly higher MEY (5647 kg/ha) closely followed by maize + mung bean (1+1) and it was 34.8 percent higher than sole maize (4190 kg/ha). Maize Equivalent Yield was found positively correlated with inter crop seed yield (r = 0.80), Aggresivity of intercrop (r = 0.93) and Competitive ratio of intercrop (r = 0.89), while it was negatively correlated with maize seed yield (r = -0.74), Aggresivity of maize crop (r = -0.93) and Competitive ratio of maize (r = -0.84). Similar reduction in equivalent yield of sole crop over inter cropped treatment was observed by Padhi *et al.*, 2010.

Relative Crowding Coefficient (RCC)

RCC was significantly affected by intercropping systems. Maize crop was recorded with higher RCC values which shows the higher competitive ability and relative dominance over intercrop out of the planting patterns, intercropping of maize with intercrop in 1:1 pattern was recorded with higher RCC_{maize} compared to paired row planting pattern. Among all intercropping treatments, maize + urd bean (1:1) was recorded with significantly higher RCC_{maize} (4.53) closely followed by maize + cluster bean/ mung bean (1:1), which also resulted in significantly higher seed yield of maize compared to other intercropping treatments. Among intercrops, urd bean and cluster bean intercropped with maize in 1:1 pattern was recorded with lower $RCC_{intercrop}$ (0.27) over other planting patterns, which shows the lower competitive ability and recessiveness against maize in these treatments. Among all intercropping systems, paired row planting of maize at 60:105 cm along with two rows of mung bean in between two pairs was recorded with significantly higher $RCC_{intercrop}$ (1.19) closely followed by paired row planting of maize at 60:105 cm along with two rows of soybean ($RCC_{intercrop}$ = 1.15). Out of the planting patterns tested, paired row planting of maize at 60:105 cm along with two rows of intercrops was recorded with significantly higher RCC_{system} over intercropping in 1:1 planting pattern. Among all intercropping systems, paired row planting of maize at 60:105 cm along with two rows of mung bean in between two pairs was recorded with significantly higher RCC_{system} (3.73) closely followed by paired row planting of maize at 60:105 cm along with two rows of soybean. RCC_{maize} and $RCC_{intercrop}$ were found positively correlated with their seed yield (r= 0.88 and r= 0.88), Competitive ratio (r= 0.78 and r= 0.99) and Aggresivity (r= 0.34 and r= 0.85), respectively. RCC_{system} was found positively correlated with maize equivalent yield (r= 0.96), ATER (r= 0.79) and LER (r=0.99).

Competitive Ratio (CR)

Competitive ratio was significantly affected by intercropping treatments. Maize was recorded with higher CR values compared to intercrops, which shows the more competitive nature of maize over intercrops. Among intercrops, mung bean and soybean showed higher competitive nature compared to urd bean and cluster bean against maize crop. Out of the planting patterns studied, 1:1 planting pattern of intercropping recorded higher CR values compared to paired row planting of maize along with two rows of intercrop. Among all intercropping treatments, maize + urd bean (1:1) was recorded with significantly higher CR_{maize} (4.00) closely followed by maize + cluster bean (1:1) with CR_{maize} (3.92), while paired row planting of maize at 60:105 cm along with two rows of mung bean in between two pairs was recorded with significantly higher $CR_{intercrop}$ (0.75) closely followed by paired row planting of maize at 60:105 cm along with two rows of soybean (0.74). CR_{maize} and $CR_{intercrop}$ were found positively correlated with their seed yield (r= 0.95 and r= 0.88), Aggresivity (r= 0.83 and r= 0.84) and RCC (r= 0.78 and r= 0.99), respectively.

Aggresivity (A)

Maize and intercrops were recorded with positive and negative values of Aggresivity (A) in all

intercropping systems, respectively, which shows the higher aggresivity or dominance of maize over intercrops in all intercropping systems. Among intercrops, cluster bean and urd bean were recorded with significantly higher "A" values of -0.31 and -0.30, respectively compared to mung bean and soybean, which shows the less competitive nature and dominated nature of urd bean and cluster bean against maize. Among all intercropping systems, paired row planting of maize at 60:105 cm along with two rows of cluster bean in between two pairs was recorded with significantly higher Aggresivity both for maize (+ 0.31) and cluster bean (-0.31) closely followed by paired row of maize at 60:105 cm along with two rows of urd bean and maize + urd bean/ cluster bean (1:1). Aggresivity of maize and intercrop was found positively correlated with competitive ratio with "r" values of 0.83 and 0.84, respectively. Seed yield of maize and intercrop was also found positively correlated with Aggresivity with "r" value of 0.73 and 0.92, respectively.

Land Equivalent Ratio (LER)

Non significant variation was observed for maize LER among all the intercropping systems. Higher LER for maize (0.82) was recorded with maize + urd bean (1:1) closely followed by maize + cluster bean (1:1) may be due to higher maize yield in these intercropping treatments compared to others. Irrespective of planting patterns among intercrops, mung bean followed by soybean were recorded with significantly higher intercrop LER. Among all the intercropping treatments, paired row planting of maize at 60:105 cm along with two rows of mung bean in between two pairs was recorded with significantly higher intercrop LER (0.50) closely followed by paired row of maize at 60:105 cm along with two rows of soybean (0.49). All the intercropping systems except paired row of maize (60:105 cm) + 2 rows of mung bean were recorded with intercrop LER values less than 0.5, which indicates the disadvantage of intercropping systems (Muhammad *et al*, 2008).

System LER was affected significantly by different intercropping treatments. All intercropping systems were recorded with LER values higher than one which shows the relative advantage of intercropping over sole planting of maize. Out of the planting patterns followed for intercropping, paired row planting of maize at 60:105 cm along with two rows of intercrop in between two pairs was recorded with higher LER compared to maize + intercrop in 1:1 planting. Irrespective of planting patterns, the treatments having mung bean and soybean as intercrop were recorded with significantly higher LER compared to the treatments where urd bean and cluster bean were taken as intercrop. Among all treatments, paired row planting of maize at 60:105 cm along with two rows of mung bean in between two pairs was recorded with significantly higher LER (1.29) closely followed by paired row planting of maize (60:105 cm) + two rows of soybean (1.27), which shows a yield advantage of 29 per cent than sole maize. System LER was found positively correlated with inter crop seed yield (r= 0.92), Aggresivity of intercrop (r= 0.95), ATER (r= 0.79) and Competitive ratio of intercrop (r=0.96),

TABLE 2
Economic evaluation of Maize based intercropping systems

Treatments	VC (Rs/ha)	TC (Rs/ha)	Total returns (Rs/ha)	Net Returns (Rs/ha)	BCR	VCR	Per day returns (Rs./ha/day)	MAI (Rs./ha)
Sole Maize	38255	77380	78612	1231	1.02	0.02	10.3	
Sole Soybean	29147	51129	66997	15868	1.31	0.31	133.3	
Sole Urdbean	18003	34898	44853	9955	1.29	0.29	83.7	
Sole Clusterbean	20765	41975	41653	-323	0.99	-0.01	-2.7	
Sole Mungbean	17853	34885	86388	51503	2.48	1.48	432.8	
Maize + Soybean (1:1)	43279	82404	93436	11032	1.13	0.13	92.7	15765.3
Maize + Urdbean (1+1)	32327	54309	76195	21885	1.40	0.40	183.9	2549.3
Maize + Clusterbean (1+1)	20960	37855	74940	37084	1.98	0.98	311.6	1885.0
Maize + Mungbean (1+1)	23865	45075	101509	56434	2.25	1.25	474.2	12581.6
Paired row maize (60:105 cm) + 2 rows of soybean	42651	81776	95282	13506	1.17	0.17	113.5	20206.6
Paired row maize (60:105 cm) + 2 rows of Urdbean	31929	53912	76949	23037	1.43	0.43	193.6	6226.3
Paired row maize (60:105 cm) + 2 rows of Clusterbean	20591	37486	75422	37937	2.01	1.01	318.8	3950.0
Paired row maize (60:105 cm) + 2 rows of Mungbean	23478	44688	106022	61335	2.37	1.37	515.4	15284.0
CD at 5%				-	-			8372.0
SEm+				-	-			2733.6

while it was negatively correlated with maize seed yield (r= -0.87), Aggresivity of maize crop (r= -0.95) and Competitive ratio of maize (r= -0.93).

Area-Time Equivalency Ratio (ATER)

Intercropping treatments affected ATER significantly. In both the planting patterns of intercropping soybean intercropped with maize resulted in ATER values more than one, which indicates a more efficient use of area-time (hectare-days) under these intercropping systems and vice-versa (Muhammad *et al*, 2008). Irrespective of intercrops paired row planting of maize along with two rows of intercrop was recorded with higher ATER values than intercropping in 1:1 planting pattern. Among all the intercropping treatments, paired row planting of maize at 60:105 cm along with two rows of soybean in between two pairs was recorded with significantly higher ATER (1.20) closely followed by maize + soybean in 1:1 planting (1.16). ATER was found positively correlated with Maize Equivalent yield (r= 0.63), LER (r= 0.80) and RCC (r= 0.79).

Monetary Advantage Index (MAI)

Intercropping systems affected the MAI significantly. Irrespective of intercrops, out of the planting patterns studied paired row planting of maize at 60:105 cm along with two rows of intercrops was found with higher MAI compared to 1:1 planting pattern of intercropping. In both the planting patterns of intercropping mung bean and soybean intercropped with maize recorded with higher MAI compared to urd bean and cluster bean intercropping with maize. Among all intercropping systems, paired row planting of maize at 60:105 cm along with two rows of soybean in between two pairs was recorded with significantly higher MAI (20207 Rs./ha) closely followed by maize + soybean in 1:1 planting and mung bean intercropped with maize in both the planting patterns of intercropping. ATER was found positively correlated with Maize Equivalent yield (r= 0.63), LER (r= 0.80) and RCC (r= 0.79).

ECONOMICS

All intercropping systems except maize intercropped with soybean were recorded with lower variable and total costs. Compared to sole planting of maize. Among planting patterns, intercropping in 1:1 planting pattern was recorded with higher amount of variable and total costs compared to paired row planting of maize with intercrops. Maize intercropped with soybean followed by urd bean in both planting patterns were recorded with higher costs compared to cluster bean and mung bean intercropped with maize.

Among all the sole and intercropping systems, mung bean sole and maize intercropped with mung bean followed by soybean in both planting patterns were recorded with higher total and net returns compared to sole maize. Paired row planting of maize at 60:105 cm along with two rows of mung bean in between two pairs was recorded with maximum total and net returns (Rs.1,06,022 and 61,335/ha with an edge of 34.8 and 4882 percent over sole maize, respectively) closely followed by maize + mung bean (1+1) with total (Rs. 101509 and 56434/ha with an edge of 29.1 and 4484 percent over sole maize, respectively). All intercropping systems were recorded with higher net return compared to sole maize. Irrespective of intercrops, paired row planting of maize along with two rows of intercrop was recorded with higher BCR values than intercropping in 1:1 pattern. Among all intercropping systems, paired row planting of maize (60:105 cm) along with two rows of mung bean was recorded with higher BCR (2.37), VCR (1.37) and per day return (Rs.515.4/ha/day) followed by maize + mung bean (1:1) with BCR (2.25), VCR (1.25) and per day return (Rs. 474.2/ha/day). All treatments except sole cluster bean were recorded with higher BCR, VCR and per day return than sole maize.

Based on one year field study it can be concluded that to gain relative advantages in terms of maize equivalent yield, land equivalent ratio, net return, B:C and more over to sustain our natural resources, the maize growers should go for intercropping of maize having paired row planting of maize (60:105 cm) along with two rows of mung bean in between two pairs followed by maize + mung bean (1:1) instead of sole planting of maize.

REFERENCES

Arya, R. K., M. C. Kamboj and S. Kumar, 2015 : Performance of medium maturing maize hybrids under Haryana agro-climatic conditions. *Forage Res.,* **41**(2) : 130-134.

Guo, J., X. Liu, Y. Zhang, J. Shen, W. Han, W. Zhang, P. Christie, K. W. T. Goulding, P. M. Vitousek, F. Zhang, 2010 : Significant acidification in major Chinese croplands. *Science,* **327**: 1008-1010.

Liu, X., Y. Zhang, W. Han, A. Tang, J. Shen, Z. Cui, P.

Vitousek, J. Erisman, K. Goulding, P. Christie, A. Fangmeier, F. Zhang, 2013 : Enahanced nitrogen deposition over China, *Nature* 494. pp. 459-462.

Matson, P. A., W. J. Parton, A. G. Power, 1997 : Agricultural intensification and ecosystem properties. *Science,* **277** : 504-509.

Muhammad, A., E. M. Umer, and A. Karim, 2008 : Yield and competition indices of intercropping cotton (*Gossypium hirsutum* L.) using different planting patterns. *Tarim Bilimleri Dergisi*.,**14**(4) 326-333.

Padhi, A. K., R. K. Panigrahi, and B. K. Jena, 2010 : Effect of planting geometry and duration of intercrops on performance of Pigeon pea - Finger millet Introcropping Systems. *Indian Journal of Agricultural Research,* **44** (1): 43-47.

Pal, Mahendra, K. A. Singh, and I. P. S. Ahlawat, (1985). Cropping system research: Concept, needs and directions. Indian Society of Agronomy. *National symposium*, CSSRI, Karnal, pp.1-45.

Sanginga, N., J. Okogun, B. Vanlauwe and K. Dashiell, 2002 : The contribution of nitrogen by promiscuous soybean to maize-based cropping in the moist savanna of Nigeria. *Plant Soil,* **241** : 223-231.

Shetty, S. V. R., B. R. Ntare, A. Bationo, and C. Renard, 1995 : Millet and cowpea in mixed farming of Sahel. A review of strategies for increased productivity and sustainability. Pages 293-304 in Livestock and sustainable nutrient cycling in mixed farming systems of sub-Saharan Africa, edited by J.M. Powell, S. Fernandez Revira, T. O. Williams, and C. *Renard. Proceedings International Conference*, ILCA, Addis Ababa, Ethiopia.

Kheroar, S., B. C. Patra, 2013 : Advantages of Maize-Legume Intercropping systems. *Journal of Agricultural Science and Technlology*, 733-744.

Tilman, D., K. G. Cassman, P. A. Matson, R. Naylor, S. Polasky, 2002 : Agriculturist sustainability and intensive production practices. *Nature,* **418** : 671-677.

Willey, R.W. and M. R. Rao, 1980 : A competitive ratio for quantifying competition between intercrops. *Experimental Agriculture*. **16**:117-125.

Wittwer, R. A., B. Dorn, W. Jossi, Van der M. G. A. Heijden, 2017 : Cover crops support ecological intensification of arable cropping system. *Sci. Rep*., **7** : 41911.