Pak. J. Bot., 51(3): 1113-1120, 2019. DOI: 10.30848/PJB2019-3(45)

EFFECT OF HERBICIDES AND INTERCROPPING ON WEEDS AND YIELDS OF MAIZE AND THE ASSOCIATED INTERCROPS

SHAHIDA BIBI[1], IJAZ AHMAD KHAN[1*], ZAHID HUSSAIN[1], SAJJAD ZAHEER[2] AND SYED MEHAR ALI SHAH[3]

[1]*Department of Weed Science,* [2]*Department of Agronomy,* [3]*Department of PBG, University of Agriculture Peshawar, 25130-Peshawar, Pakistan*
[*]*Corresponding author's email: ijazahmadk@aup.edu.pk*

Abstract

Two field trials were conducted at the farm of the University of Agriculture Peshawar, Pakistan in 2014 and 2015, to investigate the effect of intercropping on maize, mungbean, cowpea and sesbania, in which maize was the main crop and the others were intercrops. A two factorial design was used. Factor A comprised of pendimethalin application as pre-emergence and no herbicide application. Factor B consisted of four mono-cropping treatments of *Zea mays* L. (maize), *Vigna radiata* (L.) R. Wilczek (mungbean), *Sesbania sesban* (L.) Merr. (sesbania), and *Vigna unguiculata* (L.) Walp. (cowpea), along with six intercropping treatments viz. 5 legumes rows and 6 maize rows in combinations i.e. mungbean+maize, cowpea+maize, sesbania+maize, and also 10 legume crops rows and 6 maize rows in combinations mungbean+maize, cowpea+maize, and sesbania+maize. The results indicated a significant influence of the years, the use of herbicide, the treatments of intercropping, and the interaction effect of the herbicide x intercropping on the yields of studied crops which meant that the differences among the observations were statistically significant. For the year effect, the mean yields were higher in 2014; while for the effect of herbicide use, the maize grain yield was higher in pendimethalin applied plots. Stating the effect of intercropping, mungbean grain yield was highest in plots of mungbean mono-cropping and lowest in mungbean: maize intercropping (sown in ratio of 5:6 rows). Cowpea and sesbania biomasses were significantly higher in herbicide plots and also in mono-cropping plots of cowpea and sesbania plots, respectively in 2014 and 2015. The values of the Land Equivalent Ratio (LER) were between 1.40 and 1.49 for all the intercropping treatments, with the highest LER calculated for sesbania-maize intercropping (10:6 rows). Therefore, the herbicide pendimethalin as pre-emergence @1.5 kg ha^{-1} in maize crop along with intercropping of any of the studied legume crops at the 1:1 row sowing ratio is the best combination for achieving desirable weed control, higher crop yields and greater LERs.

Key words: *Vigna unguiculata*, Intercropping, *Zea mays*, *Vigna radiata*, *Sesbania sesban*.

Introduction

Maize (*Zea mays*) crop which is the third most popular cereal crop in Pakistan, after wheat and rice crops, has been grown on an area of 1168.5 ha during 2014-15 with a production of 4944.2 tons at an average grain yield of 3805 kg ha^{-1} (MINFA, 2014-15). It is vulnerable to weed competition in the first 4-6 weeks of growth (Mhlanga *et al*., 2016). Several weed control methods have been utilized in past to minimize the effect of weed competition in maize, including the use of high yielding varieties, synthetic fertilizers, and pesticides, etc. However, the tested methods were either not environmentally safe or are not very efficient and effective. Modern agricultural practices heavily depend on the use of pesticides and synthesized fertilizers to reduce the crop pests (weeds, insects and diseases) aiming at improving the crop yields (Tanveer *et al*., 2018; Gurr *et al*., 2003). Even though these agricultural practices have significantly increased yield per unit area; on the other hand, resulted in increased cost of production, development of herbicide resistance in weeds, development of a negative impact on human health and crop ecology like the loss of biodiversity, water and soil contamination and habitat degradation (Susha *et al*., 2018; Sun *et al*., 2018; Mathur *et al*., 2005; Giri *et al*., 2002).

The farmers in Pakistan have extensively been using herbicides for weed control since long. Though currently the herbicide use is globally discouraged; however, it cannot be eliminated at once. The herbicides damaging effect on the environment has generated the necessity of non-chemical and environment friendly weed management in the agro-ecosystems (Bocker *et al*., 2018; Spliid *et al*., 2004; Augustin, 2003).

One of the environment friendly methods is intercropping such as cereals (maize, wheat, rice) with legumes (mungbean, cowpea, berseem etc.). Intercropping is an important agricultural practice that improves diversification of food supply (Betencourt *et al*., 2012; Dahmardeh*et al*., 2010) and gives high economic benefits (Sun *et al*., 2018; Midega *et al*., 2014). Intercropping is a best alternative to the herbicide use which reduces or suppresses the growth of weeds (Liebman & Davis, 2009). In addition, the legume-cereal intercropping is an ideal way for subsistence agriculture (Amanullah *et al*., 2006). One of the principles of intercropping is growing two crops having different root depths which help in an efficient utilization of the available resources, which a single or mono-crop cannot do (Mashingaidze, 2004). In addition, the combined yields and net income of two crops grown as intercrops are higher than pure stands (Bilalis *et al*., 2010). Legume crops improve the organic matter and soil characteristics which in turn support the growth of cereal crops (Aslam *et al*., 2003).

Keeping in view the importance of intercropping in the modern agriculture, the study was planned to evaluate the impact of herbicide use and maize-legume intercropping on yields of the respective crops, to assess the yield advantage through computation of LER and also to figure out the effect on weeds biomass in maize-legumes intercropping system.

Materials and Methods

Two consecutive field experiments on ‘the effect of chemical weed control and intercropping on yield of maize and the other intercrops were carried out in the same experimental field in the years of 2014 and 2015 at the farm of the University of Agriculture, Peshawar-Pakistan.

The experiments were designed in a two factorial RCBD, having three replications. Factor A had two treatments including one of the herbicide use (Stomp 330 EC) and the other of no-herbicide use (also may be termed as control). Whereas factor B comprised of 10 treatments i.e. maize (*Zea mays*) mono-crop (Mz), mungbean (*Vigna radiata*) mono-crop (Mb), cowpea (*Vigna unguiculata*) mono-crop (Cp), sesbania (*Sesbania* sesban) mono-crop (Sb), 5 lines of sesbania intercropped in between 6 lines of maize (having line sowing in ratio of 1:1), 5 lines of mungbean intercropped with 6 lines of maize (1:1), 5cowpea lines with 6maize lines (1:1), 10 sesbania lines with 6maize lines (having lines ratio of 2:1), 10 cowpea lines in between 6 maize lines (2:1), and 10-mungbean lines intercropped with 6 maize lines (2:1). The intercrops i.e. Sesbania, mungbean and cowpea were grown as a green manure, a grain crop, and a fodder crop, respectively. Each of the experimental units (sub-plots) comprised of six maize crop rows, with each row length having 5 m keeping a space of 80 cm between two adjacent rows. Measurements were made on individual plants present in the mid three rows of the six row plots. The seeding rates for maize, sesbania, cowpea, and mungbean were 40, 25, 60, and 25 kg ha^{-1}, respectively.

The seed-bed was prepared by ploughing the field two times with the help of mould-board plough that was followed by one time harrowing. Sowing was done manually and the rows were thinned to the required experimental populations after two weeks of planting of the crops’ seeds. The plantings were made with the help of hand hoe. Keeping the requirement of maize only, the recommended doses of nitrogen (150 kg as urea) and phosphorus (100 kg ha^{-1}in form of single super phosphate abbreviated as SSP) were applied uniformly to all the experiments. The application was made in a way that the full P dose and half N dose were applied at the time of sowing, while the rest of N dose was applied at the 2^{nd}irrigation stage. All other cultural practices including irrigation, thinning etc. were kept uniform and consistent for all the plots. Maize was harvested after 97 days of sowing and cowpea was harvested at the time when the first pods of the plants got completely matured and dried.

Data collection procedures: Data were collected on weed biomass (kg ha^{-1}), grain yield of maize, fresh biomass $plant^{-1}$ of sesbania and cowpea, grain yield (kg ha^{-1}) of mungbean and land equivalent ratio (LER). For fresh biomass of weeds, cowpea and sesbania, and grain yields of maize and mungbean, the mid three rows were harvested from each experimental unit, sundried, and were weighed with a spring balance. The values were then changed in to kilograms per hectare using the given formula below:

$$\text{Fresh biomass of weeds (kg ha}^{-1}\text{)} = \frac{\text{Fresh biomass of weeds (kg) x 10000 m}^2}{\text{Area harvested in square meters}}$$

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{Grain weight (kg) x 10000 m}^2}{\text{Area harvested in square meters}}$$

Maize partial LER (LERM) and partial LER of the intercrops were calculated by using the formula of Muhta & De (1980) and Willy and Rao (1980).

$$LER = (Yab/Yaa) + (Yba/Ybb)$$

where, Yaa and Ybb are yields as sole crops and Yab and Yba are yields as intercrops.

$LER_{Total} = LER_{Maize} + LER_{Mungbean}$
$= YIM/YSM + YIMb/YSMb$
$LER_{Total} = LER_{Maize} + LER_{Cow\ pea}$
$= YIM/YSM + YICp/YSCp$
$LER_{Total} = LER_{Maize} + LER_{Sesbania}$
$= YIM/YSM + YISb/YSSb$

where YSM stands for yield of sole maize, YSMb for yield of sole mungbean, YSCp for yield of sole cowpea and YSSb for yield of sole sesbania, while YIM, YIMb, YICp, and YISb for yield of Intercropped maize, mungbean, cowpea, and sesbania, respectively.

In the figures below in the results and discussion chapter, the abbreviation SM6 stands for solemaize treatments having 6 rows per unit plot, SMb15 for solemungbean having 15 rows per unit plot, SCp15 for solecowpea with 15 rows, SSb15 for sole sesbania with 15-rows. The rest were intercropping treatments including 5 Sb6M i.e. 5 sesbania lines intercropped in between 6 maize lines i.e. in 1:1 ratio, 5 Mb6M indicates 5 mungbean lines sown in ratio of 1:1 in between 6 maize lines, 5 Cp6M expresses 5 cowpea rows intercropped with 6 maize rows,10 Sb6M which means 10 sesbania rows intercropped with 6 maizerows, 10 Cp6M i.e. 10 cowpea rows with 6 maize rows, and 10 Mb6M showing 10 mungbean rows intercropped with 6 maize rows.

Data analysis: The combined analyses were conducted for both of the two-year data, using the required ANOVA procedure. In addition, the separate analyses of the two years data were also performed. Both the main and interaction effects were statistically analyzed. Then, using the Least Significant Difference test, the significant means were separated (Steel & Torrie, 1980).

Results and Discussion

Fresh weed biomass (kg ha^{-1}): Weeds density and biomass play key role in the ultimate yield of the infested crop. The years had a significant effect on fresh weed biomass (FWB) (Table 1). In 2015, the FWB was significantly higher (1995 kg) than that in 2014 (1641 kg ha^{-1}) which could be due to the variation in prevailing weather. The use of herbicide, the intercropping and the interaction effect also showed a significant influence on the FWB in the two years study. The mean FWB was 530 kg in the treatments of no herbicide use as compared to the plots where herbicide was used (2752 kg ha^{-1}). As a universal truth, a one kg biomass of weeds in a field will mean one kg loss in the yield of the target crop (Rao *et al.*, 2000; Baumann *et al.*, 2000). For intercropping effect, the lowest FWB was noted in the plots of cowpea+maize inter cropped with a ratio of 1:1, and the highest in the maize mono-crop plots. However, the weed biomass lowest value was statistically at par with the intercropping treatment of mungbean+maize sown in ratio of 1:1. Moreover, the intercropping of legumes: maize in ratio of 1 row:1 row showed greater weed biomass as compared to the treatment of legumes: maize sown in 2:1 ratio. Evidently, the intercropping method decreased the per unit area weed biomass. Intercropping therefore helped in better weed suppression compared with sole cropping (Susha *et al.*, 2018; Banik *et al.*, 2006; Saucke & Ackermann, 2006; Singh & Balyan, 2000). The reason for the reduced FWB was the limited space, light and fractional nutrients availability for weeds as compared to the sole plots. A significant interaction effect of herbicide use and intercropping was recorded on FWB which conformed to the findings of Ghosheh *et al.* (2005). The figures 1(a) and 1(b) depict the interaction effects.

Grain yield of *Zea mays* (maize) (kg ha^{-1}): Statistically a significant effect was recorded for the year effect on maize grain yield (2536 kg ha^{-1}) in 2014, significantly higher as compared to the yield in 2015 (2114 kg ha^{-1}) (Table 2). Moreover, a statistically significant effect was noted for the herbicide use, the intercropping and their interaction on the grain yield of maize. In 2014, significantly higher maize grain yield (3098 kg) was recorded in pendimethalin treated plots and lower yield (1974 kg ha^{-1}) was noted in the control plots where no herbicide was used. In addition, the maize grain yield (2582 kg ha^{-1}) in plots of herbicide was statistically higher than the no herbicide use treatments (1645 kg ha^{-1}). Limited soil resources availability results in lower grain yield due to higher weed competition even in higher crop density (Sobkowicz & Tendziagolska, 2005).

Table 1. Fresh weed biomass as affected by herbicide and intercropping in 2014-15.

Treatments	Fresh weed biomass (kg ha^{-1})	
	2014	2015
Herbicide treatments (A)		
Herbicide used	529 b	689 b
Herbicide not used	2751 a	3302 a
$LSD_{0.05}$	*	*
Intercropping treatments (B)		
Sole maize crop	2389 a	2906 a
Sole mung-bean crop	1837 c	2231 c
Sole sesbania crop	2159 b	2622 b
Sole cowpea crop	2056 b	2501 b
5sesbania + 6maize rows (1:1)	1193 g	1455 g
5mungbean + 6maize rows (1:1)	1373ef	1672ef
5 cowpea + 6maize rows (1:1)	1101 g	1346 g
10sesbania + 6maize rows (2:1)	1329 f	1620 f
10 cowpea + 6maize rows (2:1)	1457 de	1770 de
10mungbean + 6maize rows (2:1)	1515 d	1835 d
$LSD_{0.05}$	113.8	1.99
Interaction	162.1	2.82
Year means	1640 b	1995 a
$LSD_{0.05}$	*	*

The means having varying letters show significant difference at α = 5%; * = Significantly different

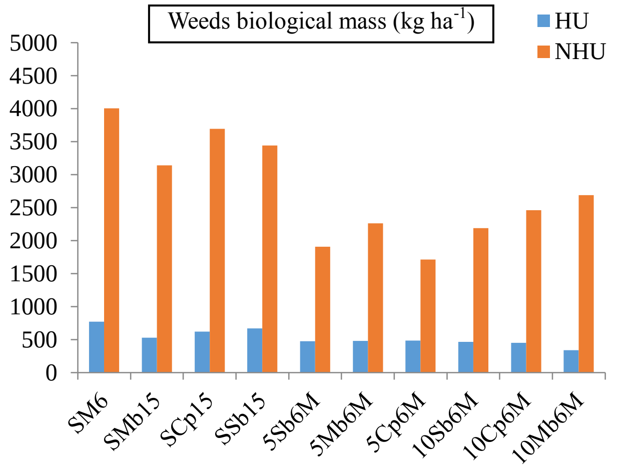

Fig. 1(a). Herbicides and intercropping interaction effect on weedsfresh biomass in 2014.
FW = Fresh weeds, HU = Herbicide used, NHU = No herbicide used

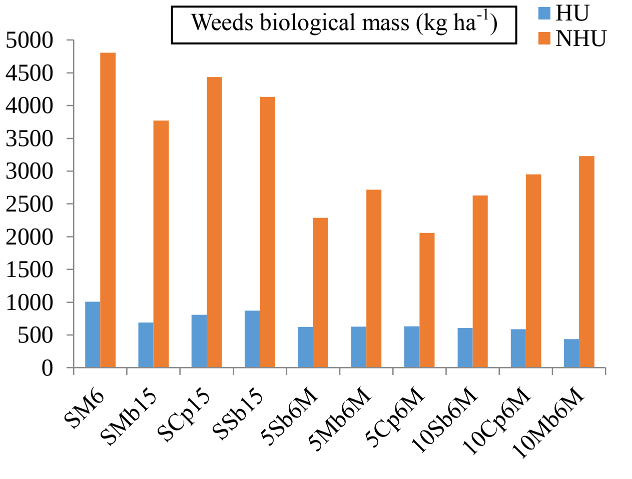

Fig. 1(b). Herbicides and intercropping interaction effect on weedsfresh biomass in 2015 in Peshawar.
NHU = No herbicide used; HU = Herbicide used;
SM6 = sole maize plots having six rows; SMb15 = sole mungbean plots having 15 rows; SCp15 = sole cowpea treatments keeping 15 rows per unit plot; SSb15 = sole sesbania treatments having 15rows per unit plot; 5Sb6M =five sesbania rows intercropped with six maize rows; 5Mb6M = five mungbean rows with six maizerows; 5Cp6M =five cowpea rows with six maizerows; 10Sb6M = ten sesbania rows with six maize rows; 10Cp6M =ten cowpea rows with six maize rows; 10Mb6M = ten mungbean rows intercropped with six maizerows

The intercropping significantly affected the maize yield. The grain yield was highest (3179 kg ha^{-1}) in maize mono-crop treatments. Thus, a decline in the yield of grains was noticed when intercropping density was increased. The maize mono-crop treatment was followed by the treatment of intercropping 5 legume rows with 6 maize rows which showed higher grain yield than treatments of 10 legume rows intercropped with 6 maize rows in both of the two years. The unit plant yield was thus decreased with surge in the plants population of the respective crops. Analogously, a decrease in maize grain yield was reported by Ibrahim *et al.* (1995) due to increase in the plants population. Therefore, maize competitiveness can be improved by increasing its planting density. The interaction effect can be observed in the Fig. 2(a) and 2(b) for 2014 and 2015, respectively. Even though the maize grain yield was influenced by the treatments of intercropping; however the extent of reduction in yield was greatly dependent on the species that were intercropped. Maize plants, at higher densities, were susceptible to competition from weeds species and intercropped species both (Liebman & Davis, 2009).

Table 2. Grains yield of maize as affected by herbicide treatment and intercropping treatments.

Treatments	Maize grains yield (kg/ha)	
	2014	2015
Herbicide treatments (A)		
Herbicide used	3098a	2582a
Herbicide not used	1974b	1645b
$LSD_{0.05}$	*	*
Intercropping treatments (B)		
Sole maize (6 rows)	3179a	2649a
5-rows-sesbania + 6-rows-maize	2591c	2159c
5-rows-mungbean + 6-rows-maize	2482cd	2068cd
5-rows-cowpea + 6-rows-maize	2794b	2329b
10-rows-sesbania + 6-rows-maize	2276e	1897e
10-rows-cowpea + 6-rows-maize	2392de	1994de
10-rows-mungbean + 6-rows-maize	2040f	1700f
$LSD_{0.05}$	160.0	133.4
Interaction (A x B)	227.4	189.5
Year means	2536a	2114b
$LSD_{0.05}$	*	*

The means having varying letters show significant difference at α = 5%;
* = Significantly different, ** = Highly significant

Fresh biomass of *Sesbania sesban* (Sesbania) (kg ha^{-1}): A significant years' effect was recorded on the Sesbania fresh biomass (Table 3). The year 2014 had a higher fresh biomass of Sesbania (2265 kg ha^{-1}) than 2015 (1888 kg ha^{-1}). The herbicides, intercropping treatments and their interactions all had a significant effect on fresh biomass of Sesbania during the two years study. During 2014, the sesbania fresh biomass was higher in herbicide plots (2463 kg ha^{-1}) than in the no-herbicide-use plots (2069 kg ha^{-1}) followed by the year 2015 in the same fashion (Table 3). In conclusion, the highest Sesbania biomass was due to the effective weed control in the treatments of herbicides, as the increase in biomass of weeds triggered a decline in the crop biomass (Rao, 2000). Following the mono-crop plots of sesbania, in terms of biomass, the intercropping of 10 sesbania rows with 6 maize rows resulted in 2201 kg ha^{-1} yield. The lowest biomass was 1767 kg ha^{-1} recorded in treatment of 5 sesbania rows intercropped with 6 maize rows. A similar trend was found in 2015 with values of 2358, 1834, and 1473 kg ha^{-1}for sole sesbania plots, 10 sesbania rows intercropped with 6 maize rows and 5 sesbania rows intercropped with 6 maize rows, respectively.

It is thus understandable that the fresh biomass of sesbania was highest in Sesbania mono-cropping treatments due to sowing of Sesbania only. On the other hand, in the presence of 6-rows-maize crop in the same unit area, the Sesbania biomass got decreased as compared to the biomass in sole Sesbania plots. As a result, the intercropping of 10-rows-sesbania + 6-rows-maize had a higher biomass of Sesbania as compared to that in the plots of 5-rows-sesbania intercropped with 6-rows-maize. The intercropping of legumes with maize crop thus resulted in a reduced yield of the main crop and the intercrops both. In addition to weed suppression, the intercropping of Sesbania with maize is a good strategy for soil improvement through N-fixation, green manuring, more fodder production for livestock, higher net income from the same land, and biodiversity maintenance etc. all of which are favorable for maize crop (Ghosheh *et al.*, 2005). Higher species richness may be linked with nutrients cycling and thus help in regulating soil fertility and reduce losses of nutrients through leaching (Hauggaard-Nielsen *et al.*, 2001).

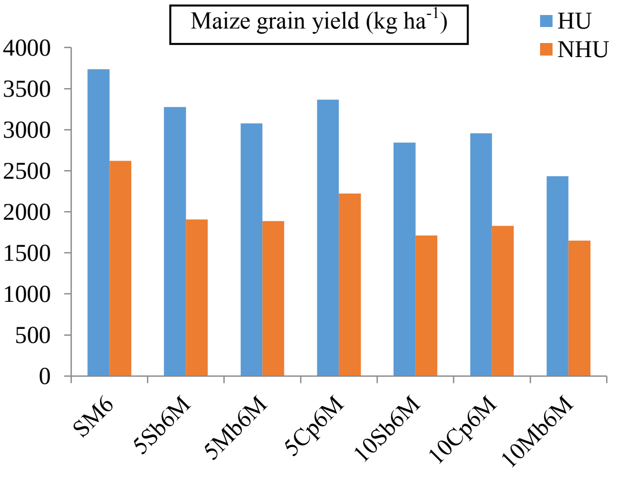

Fig. 2(a). Effectof the interaction of the herbicide treatment (factor a) and intercropping treatment (factor b) on maize grain yield in Peshawar during 2014.

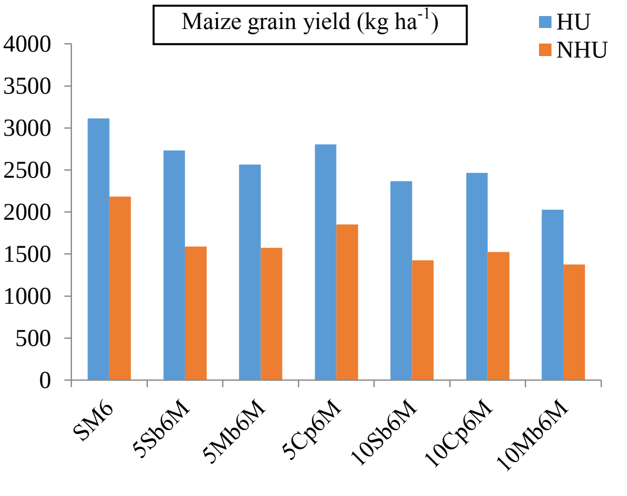

Fig. 2(b). Effect of the interaction of the herbicide treatment (factor a) and intercropping treatment (factor b) on maize grain yield in Peshawar during 2015.
SM6 = sole plots of maize having six rows per unit plot; 5Sb6M =five sesbania rows intercropped with six maize rows; 5Mb6M =five mungbean rows intercropped with six maize rows; 5Cp6M =five cowpea rows intercropped with six maize rows; 10Sb6M = Ten sesbania rows intercropped with six maize rows; 10Cp6M = Ten cowpea rows intercropped with six maize rows; 10Mb6M = Ten mungbean rows intercropped with six maize rows
NHU = No-herbicide-used, HU = Herbicide-used,

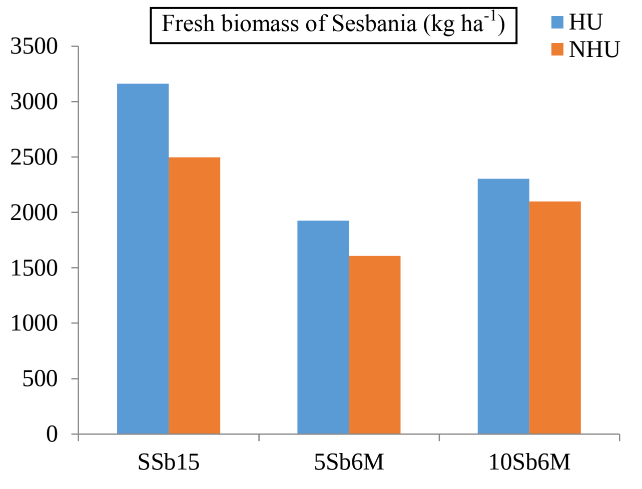

Fig. 3(a). Herbicide use and intercropping interaction effect on fresh biomass of Sesbania.

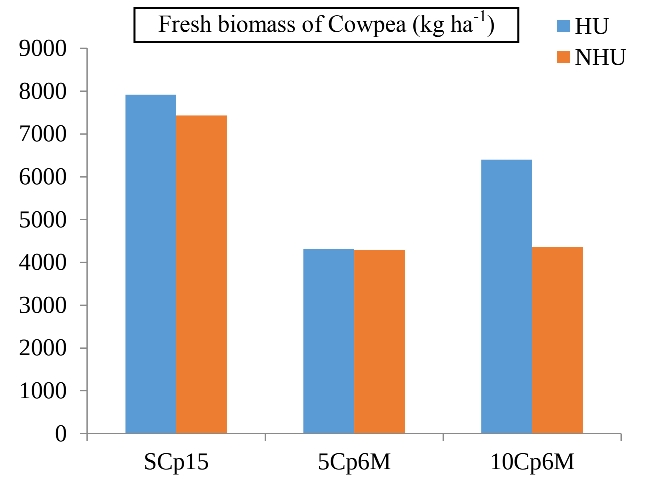

Fig. 4(a). Herbicide and intercropping interaction effect on fresh biomass of cowpea in2014.

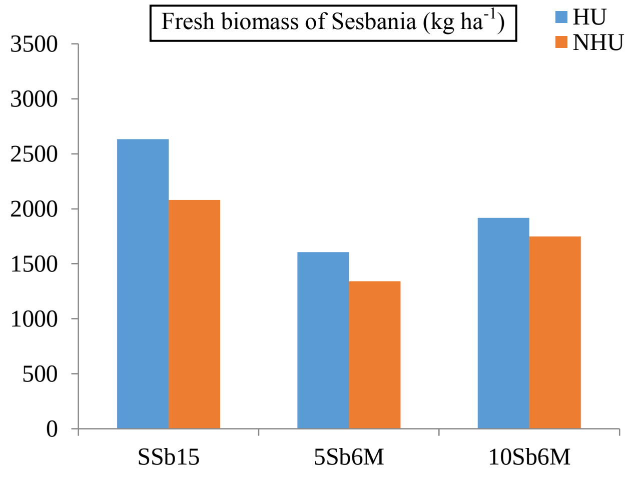

Fig. 3(b). Herbicide use and intercropping interaction effect on fresh biomass of Sesbania.
HU = No-herbicide-use, HU = Herbicide-use, SSb15 = sole plots of sesbania having 15rows, 5Sb6M = five sesbania rows intercropped with six maize rows, 10Sb6M = Ten sesbania rows intercropped with six maize rows

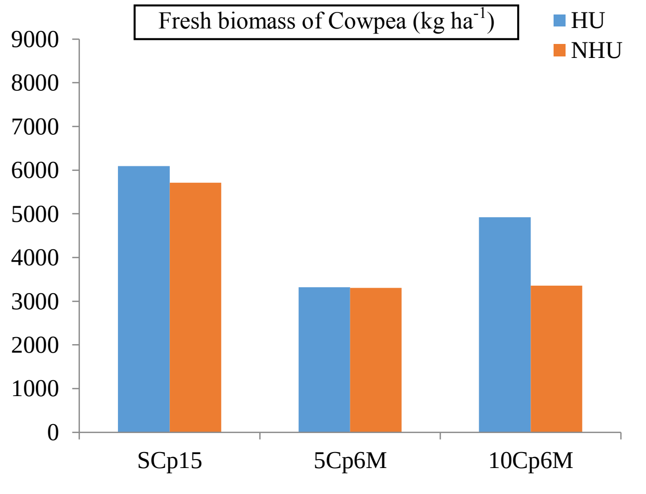

Fig. 4(b). Herbicide and intercropping interaction effect on cowpea fresh biomass in 2015
N.H.U.stands for No Herbicide Use; H.U.stads for Herbicide Use; SCp15 = sole plots of cowpea having 15 rows of the crop; 5Cp6M = five cowpea rows intercropped with six maize rows; 10Cp6M =Ten cowpea rows intercropped with six maizerows

The herbicide and intercropping interaction (AxB) had a significant effect on fresh biomass of Sesbania. The Figs. 3(a) and 3(b) indicate the interaction effects of 2014 and 2015, respectively. Sesbania fresh biomass was highest in sole Sesbania plots under the treatments of herbicides while the intercropping plots of 5-rows-sesbania + 6-rows-maize showed the lowest biomass of sesbania. The values of the herbicide use and no herbicide use treatments were significantly different under the same sole or intercropping category in both of 2014 and 2015 experiments.

Fresh biomass of cowpea (*Vigna unguiculata*) (kg ha^{-1}): The selection of cowpea for the experiments was based on being a fodder crop. The point of interest was increase in the biomass, because the increase in fresh biomass of a fodder crop will mean increase in the total production. There was a significant effect of the years on the cowpea biomass (Table-4). The fresh cowpea biomass was 5787 kg ha^{-1} in 2014 which was higher than that in 2015 (4451 kg ha^{-1}).The herbicide treatments, intercropping treatments and their interactions also had a significant effect on cowpea fresh biomass, in both of the two years experiments. The cowpea fresh biomass was higher in herbicide plots (6212 kg ha^{-1}) than in the plots of no herbicide use (5363 kg ha^{-1}) in 2014 as well as in 2015 (4778 &4125 kg ha^{-1}, respectively). The highest biomass in the herbicidal plots was due to the effective weed control. Rao (2000) rightly mentioned that 1 kg weed biomass in a field was directly the loss of 1 kg of crop biomass.

The highest biomass of cowpea (7677 kg/ha) was found in sole cowpea plots which was followed by the plots of 10 cowpea rows intercropping with 6 maize rows (5382 kg). The lowest biomass (4304 kg ha^{-1}) of cowpea was recorded in the treatment of 5cowpea rows intercropped with six maize rows. The reason for the highest biomass of cowpea in the sole cowpea plots was that only cowpea crop was grown in that plot. On the other hand, when there were additional six rows of maize crop in the same unit size, the biomass of cowpea biomass was less than that in the sole plots of cowpea.

Moreover, the herbicide and intercropping interaction effect was significant too on fresh biomass of cowpea {Fig. 4(a) and 4(b)}. The sole cowpea plots had the highest cowpea fresh biomass under the treatments of herbicide use. The difference between the biomasses in herbicide plots and non-herbicide plots were negligible under the similar sole crop or intercropping category. However, this difference was obtained significant in the intercropping treatment of 10 cowpea rows with six maize rows (2:1) in 2014 and 2015 both.

Vigna radiata **(Mungbean) grain yield (kg ha^{-1}):** Mungbean is a leguminous crop which not only gives its yield but also helps improve soil fertility. Therefore, it was selected as a grain crop for intercropping with maize. Table 5 shows the significant effect of the years on mungbean grain yield. A higher grain yield (341 kg ha^{-1}) in 2014 was obtained as compared to that in 2015 (296 kg ha^{-1}). A significant effect of not only the herbicides and intercropping but also of their interaction effect was recorded for the mungbean grain yield in 2014 and 2015 both. A significantly higher grain yield (366 kg ha^{-1}) was recorded in 2014 for herbicide (pendimethalin) as compared to plots of no herbicide use (315 kg ha^{-1}). In the same fashion, the herbicide treatments gave grain yield of 25 kg ha^{-1} that was higher than that in the no herbicide used plots (22 kg ha^{-1}).

There was a significant effect of the intercropping on the grain yield of mung bean crop. The mung bean grain yield was highest (427) in plots of mung bean mono-crop. The decline was however in the same fashion in both of the years. The highest grain yield of mung bean(427 kg ha^{-1}) was obtained from sole mung bean plots, followed by the intercropping of 5-rows-mungbean:6-rows-maize (326 kg ha^{-1}) and intercropping of 10-rows-mungbean:6-rows-maize (10 kg ha^{-1}). The highest to lowest values in 2015 were 27, 25, and 18 kg ha^{-1}for grain yield of mungbean. It is obvious that increasing the no. of individual plants per square meter will decline the grain yield of mungbean as a result of the intra and/or inter specific competition (Polthanee & Trelo-ges, 2003).

There was a significant effect of the interaction treatments of herbicide and intercropping on grain yield of mungbean {Fig. 5(a) and 5(b)}. The mungbean grain yield was the highest in mungbean mono-cropping under herbicide used plots, while the lowest grain yield was recorded in treatment of mungbean intercropped with maize in ratio of 10 rows:6 rows under plots of no herbicide use, in 2014 and 2015 both.

Land equivalent ratio (LER): The LER, a key factor in system of intercropping, computes the net profit obtained from a known piece of land by growing more than one crop at a time. The values of LER bigger than one in the intercropping treatments indicated the yield benefit of intercropping over maize mono cropping in both the years of 2014 and 2015. The biggest value of LER (1.494) calculated in treatment of 10-rows-sesbania+6-rows-maize, followed by plots of 10-rows-cowpea+6-rows-maize (with LER value of 1.453); while, the smallest LER (1.406) was recorded for intercropping of 10-rows-mungbean and 6-rows-maize. The range of LER values was between 1.406 and 1.494 in the intercropping treatments of the year 2014. The same trend was found in the experiment of 2015. Thus, utilizing the legume crops of cowpea, sesbania, and mungbean for intercropping with maize would enhance the land use efficiency (Olufajo, 1992; Agbaje *et al.*, 2002). The use of land resource efficient where the shortage of land entices the peasants to cultivate more than one crop on the same small piece of land is one of the key reasons for including intercropping method in the conventional farming system (O'Callaghan *et al.*, 1994). Other researchers who received higher LER from maize intercropping were Patra *et al.* (1990) who intercropped maize with pigeon pea, Mandimba (1995) with groundnut, and Kalia *et al.,* (1992) and Ullah *et al.,* (2007) with soybean. All of the intercropping systems do have the potential of giving substantially higher net income over single-cropping.

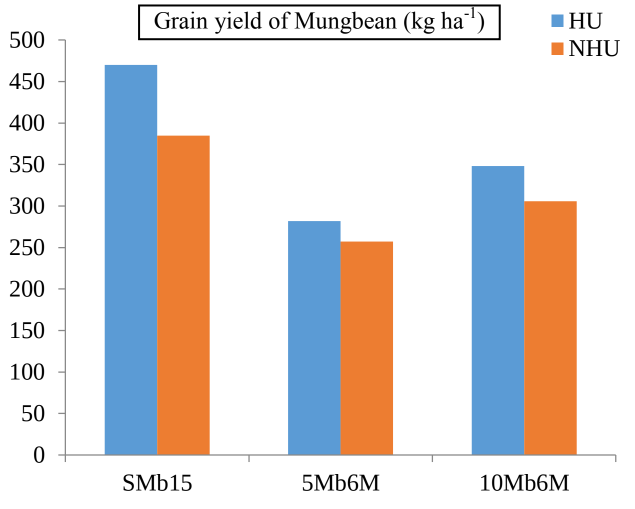

Fig. 5(a). Herbicide use and intercropping interaction effect on mungbeangrain yield in 2014.

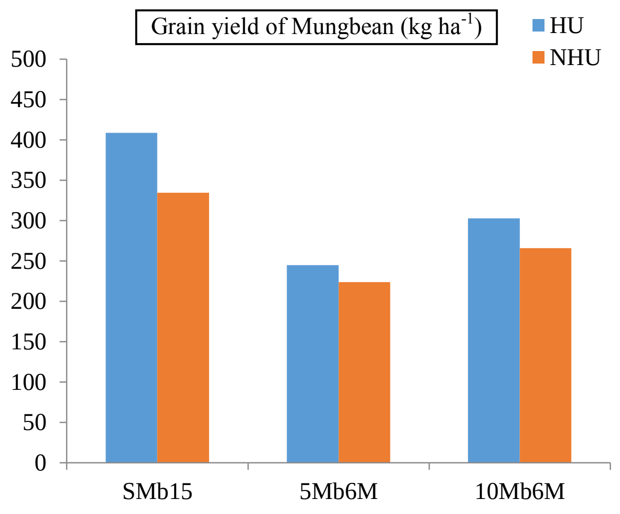

Fig 5(b). Herbicide use and intercropping interaction effect on mungbean grain yield in 2015
N.H.U.stands for No-Herbicide-Use, HU for Herbicide Use, SMb15 = solemungbean plots having 15rows; 5Mb6M = five rows of mungbean intercropped with six rows of maize; 10Mb6M = Tenrows of mungbean intercropped with six rows of maize

Table 3. Sesbaniafresh biomass as affected by treatments of herbicide use and intercropping in 2014 and 2015.

Treatments	Fresh biomass of sesbania (kg ha^{-1})	
	2014	2015
Herbicide treatment (A)		
Herbicide used	2463 a	2052 a
Herbicide not used	2068 b	1723 b
$LSD_{0.05}$	*	*
Intercropping treatments (B)		
Sole Sesbania (15 rows)	2829 a	2357a
5-rows-Sesbania: 6-rows-maize	1767 c	1472 c
10-rows-Sesbania: 6-rows-maize	2200 b	1833 b
$LSD_{0.05}$	89.21	138.3
Interaction (A x B)	207.4	172.9
Year means	2265 a	1888 b
$LSD_{0.05}$	*	*

The means having varying letters show significant difference at α = 5%
* = Significantly different

Table 4.Cowpea fresh biomass as influenced by herbicide and intercropping treatments in 2014 and 2015.

Treatments	Fresh biomass of cowpea (kg ha^{-1})	
	2014	2015
Herbicide treatments (A)		
Herbicide used	6212 a	4778 a
Herbicide not used	5362 b	4125 b
LSD Values	*	*
Intercropping treatments (B)		
Sole crop of cowpea (15-rows)	7677 a	5905 a
5 Cowpea rows + 6 rows of maize	4304 c	3311 c
10 Cowpea rows + 6 rowsofmaize	5382 b	4140 b
$LSD_{0.05}$	488.3	375.6
Interaction effect (AxB)	925.1	711.9
YEAR means	5787 a	4451b
$LSD_{0.05}$	*	*

The means having varying letters show significant difference at α = 5%
* = Significantly different

Table 5. Mungbean grain yield as affected by the herbicide and intercropping treatments.

Treatments	Grain yield of mungbean (kg ha^{-1})	
	2014	2015
Herbicide treatments (A)		
Herbicide used	366 a	318 a
Herbicide not used	315 b	275 b
$LSD_{0.05}$	*	*
Inter-cropping treatments (B)		
Sole mungbean crop (15 rows)	427 a	371 a
5-rows-mungbean:6-rows-maize	269 c	234 c
10-rows-mungbean:6-rows-maize	326 b	284 b
$LSD_{0.05}$	10.02	8. 80
Interaction effect (AxB)	12.01	10.39
Year (means)	341 a	296 b
$LSD_{0.05}$	*	*

The means having varying letters show significant difference at α = 5%
* = Significantly different

Conclusion

The pre-emergence herbicide, pendimethalin @ 1.5 kg ha^{-1} is very effective in weed management and crop yield enhancement. In addition, the intercropping is also an environmental-friendly weed control tool. Intercropping of maize (the main crop) and the legumes (the intercrops) i.e. cowpea, mungbean and sesbania in different ratios affected the purposeful yields of each other. The LER was higher than one in all intercropping plots indicating the advantage of maize-legume intercropping system in land use efficiency. Intercropping is an economical system as indicated by the CBR values. Intercropping may also reduce reliance on chemical weed control in addition to being an environmentally safer way of managing weeds.

References

Agbaje, G.O., B.A. Ogunbodede and J.O. Makinde. 2002. Biological and economical efficiency of maize + soybean intercrop pattern in rainforest and savanna areas of Nigeria. *J. Agri. Res*., 3: 37-40.

Amanullah, M., K. Vaiyapuri and A. Alagesan. 2006. Effect of intercropping and organic manures on the yield and biological efficiencies of cassava intercropping system (*Manithot esculanta* Crantz). *Res. J. Agri. Biol. Sci.,* 2(5): 201-208.

Anonymous. 2010. Govt. of Pakistan. Economic Survey of Pakistan, 2009-2010., Finance Division, Economic Advisors Wing, Islamabad, Pakistan.

Aslam, M., I.A. Mahmood, M.B. People, G.D. Schwenke and D.F. Herridge. 2003. Contribution of chickpea nitrogen fixation to increased wheat production and soil organic fertility in rain-fed cropping. *Biol. Fertil. Soil*, 38: 59-64.

Augustin, B. 2003. Urban areas-source of pesticide contamination of surface water. In: *2nd Int. Symp. Plant Health in Urban Horticulture*, (Eds.): Balder, H., Strauch, K.H., Backhaus, G.F. (Eds.) Berlin, Germany. pp. 166-169.

Baumann, D.T., M.J. Kropf and L. Bastiaans. 2000. Intercropping leeks to suppress weeds. *Weed Res*., 40: 361-376.

Betencourt, E., M. Duputel, B. Colomb, D. Desclaux and P. Hinsinger. 2012. Intercropping promotes the ability of durum wheat and chickpea to increase rhizosphere phosphorus availability in a low P soil. *Soil Biol. Biochem*., 46: 21-23.

Bilalis, D., P. Papastylianou, A. Konstantas, S. Patsiali, A. Karkanis and A. Efthimiadou. 2010. Weed-suppressive effects of maize-legume intercropping in organic farming. *Int. J. Pest Manag*., 56(2): 173-181.

Bocker, T., W. Britz and R. Finger. 2018. Modelling the effects of a glyphosate ban on weed management in silage maize production. *Ecol. Econ*., 145: 182-193.

Chen, C., M. Westcott, K. Neill, D. Wichman and M. Knox. 2004. Row configuration and nitrogen application for barley-pea intercropping in Montana. *Agron. J.,* 96: 1730-1738.

Dahmardeh, M., A. Ghanbari, B.A. Syahsar and M. Ramrodi. 2010. The role of intercropping maize (*Zea mays* L.) and Cowpea (*Vigna unguiculata* L.) on yield and soil chemical properties. *Afr. J. Agri. Res*., 5: 631-636.

Ghosheh, H.Z., E.Y. Bsoul and A.Y. Abdullah. 2005. Utilization of alfalfa (*Medicago sativa* L.) as smother crop in field corn (*Zea mays* L.). *J. Sust. Agri.* 25: 5-17.

Giri, S., S.B. Prasad, A. Giri and G.D. Sharma. 2002. Genotoxic effects of malathion, an organophosphorus insecticide, using three mammalian bioassays in vivo. *Mut. Res.,* 514: 223-231.

Gurr, G.M., S.D. Wratten and J.M. Luna. 2003. Multi-functional agricultural biodiversity: pest management and other benefits. *Basic Appl. Ecol.,* 4(2): 107-116.

Hauggaard-Nielsen, H., P. Ambus and E.S. Jensen. 2001. Interspecific competition, N use and interference with weeds in pea–barley intercropping. *Field Crops Res*., 70(2): 101-109.

Ibrahim, H.M., A.S. Kholosy, M.K. Zahran and E.E. Hassanein. 1995. Study of wild oat (*Avena fatua*) competition with wheat (*Triticum* sp.). *Ann. Agri. Sci. Egypt*. 40(2): 683-696.

Kalia, R.D., R.V. Singh and R. Singh. 1992. Performance of soybean intercropping with maize in different planting patterns under rainfed conditions of Himachal Pradesh. *Haryana J. Agron*., 8(1): 78-80.

Liebman, M. and A.S. Davis. 2009. Managing weeds in organic farming systems: an ecological approach. Organic farming: The ecological system. Francis C, editor. Madison: *American Soc. Agron*., pp. 173-196.

Mandimba, G.R. 1995. Contribution of nodulated legumes on the growth of maize under various cropping systems. *Symbiosis (Rehvt)*, 19(2/3): 213-222.

Mashingaidze, A.B. 2004. Improving weed management and crop productivity in maize systems in Zimbabwe. Ph.D. thesis, Wageningen University, Wageningen. Methods in terms of grain yield, response to applied phosphorus and monetary return from maize and cowpeas. *East Afr. Agric. Fore. J*., 42(1): 66-70.

Mathur, H.B., H.C. Agarwal, S. Johnson and N. Saikia. 2005. Analysis of Pesticide residue in blood samples from village of Punjab. CSE Report, India, pp. 1-15.

Mhlanga, B., B.S. Chauhan and C. Thierfelder. 2016. Weed management in maize using crop competition: A review. *Crop Protec*., 88: 28-36.

Midega, C.A.O., D. Salifu, T.J. Bruce, J. Pittchar and Z.R. Khan. 2014. Cumulative effects and economic benefits of intercropping maize with food legumes on *Strigahermonthica* infestation. *Field Crops Res.*, 155: 144-152.

MINFA. 2014-15. Government of Pakistan, Ministry for Food and Agriculture Division (Economic wing) Islamabad, Pakistan, pp. 18-19.

O'Callaghan, J.R., C. Maende and G.C.L. Wyseure. 1994. Modelling the intercropping of maize and beans in Kenya. *Comp. Electr. Agric*., 11: 351-365.

Olufajo, O. 1992. Response of soybean to intercropping with maize in a sub-humid tropical environment. *Trop. Oil Seeds J*., 1: 27-33.

Patra, B.C., B.K. Mandal and B.B. Mandal. 1990. Productivity of maize legume intercropping system. *Ind. J. Agri. Sci*., 34(4): 227-233.

Polthanee, A. and V. Trelo-ges.2003. Growth, yield and land use efficiency of corn and legumes grown under intercropping systems. *Plant Prod. Sci*., 6(2): 139-146.

Rao, M.R. and M.N. Mathuva. 2000. Legumes for improving maize yields and income in semi-arid Kenya. *Agri. Ecosys. Environ*., 78(2): 123-137.

Saucke, H. and K. Ackermann. 2006. Weed suppression in mixed cropped grain peas and false flax (*Camelina sativa*). *Weed Res*., 46: 453-461.

Singh, K. and J.S. Balyan. 2000. Performance of sorghum (*Sorghum bicolor*) plus legume intercropping under different planting geometries and nitrogen levels. *J. Agron.,* 45(1): 64-69.

Sobkowicz, P. and E. Tendziagolska. 2005. Competition and productivity in mixture of oats and wheat. *J. Agron. Crop Sci*., 191: 377-385.

Spliid, N.H., A. Carter and A. Helweg. 2004. Non-agricultural use of pesticides-Environmental issues and alternatives. *Pest Manag. Sci*., 60: 523.

Staver, C., F. Guharay, D. Monterroso and R.G. Muscler. 2001. Designing pest-suppressive multistrata perennial crop systems: shade-grown coffee in Central America. *Agrofore. Syst*., 53(2): 151-170.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics. A biometrical approach. 2nd Editon. McGraw Hill, Inc. USA.

Sun, T., Z. Li, Q. Wu, T. Sheng and M. Du. 2018. Effects of alfalfa intercropping on crop yield, water use efficiency and overall economic benefit in the Corn Belt of Northeast China. *Field Crops Res*., 216: 109-119.

Susha, V.S., T.K. Das, C.P. Nath, R. Pandey and S. Ghosh. 2018. Impacts of tillage and herbicide mixture on weed interference, agronomic productivity and profitability of a maize-wheat system in the Indo-Gangetic Plains. *Field Crops Res*., 219: 180-191.

Tanveer, A., M. Nadeem, A. Khaliq, T. Abbas, R. Maqbool and M.E. Safdar. 2018. Estimation of critical period of exotic invasive weed *Alternanthera philoxeroides* interference in maize. *Pak. J. Bot.*, 50(5): 1885-1892.

Ullah, A., M.A. Bhatti, Z.A. Gurmani and M. Imran. 2007. Studies on planting patterns of maize (*Zea mays* L.) facilitating legumes intercropping. *J. Agri. Res*., 45(2): 113-118.

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

(Received for publication 15 February 2018)