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RESEARCH ARTICLE

Evaluation of cultural practices for weed management in maize-based cropping system in Palam valley, Himachal Pradesh

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ABSTRACT

A study was carried out during 2017-19 at Palampur in an ongoing experiment under All India Coordinated Research Project on Weed Management (AICRP-WM). Ten weed control treatments based on hoeing, stale seed bed + hoeing, raised stale seed bed (RSSB) + hoeing, mulch, stale seed bed + mulch, raised stale seed bed (RSSB) + mulch, intercropping, crop rotation, intensive cropping and herbicide check (pendimethalin in pea/garlic and atrazine in maize) were tested during *Rabi* 2017-18 to *Kharif* 2019. There were 22 weed species in garlic and 19 weed species in maize. *Phalaris minor, Daucus carota* and *Anagallis arvensis* were the major weeds, constituting 17.0, 14.0 and 12.0 per cent, respectively of the total weed flora in garlic during 2017-18. *Commelina benghalensis L., Galinsoga parviflora* and *Ageratum* sp. were the major weeds constituting 21.0, 17.0 and 11.0 per cent, respectively of the total weed flora in maize. Maximum bulb yield (3472 kg/ha) was recorded with RSSB + hoeing and was statistically at par with herbicide check and SSB + hoeing. In maize, the highest cob yield was recorded in RSSB + mulch followed by mulch. Maize equivalent yield was higher in intercropping followed by intensive cropping and RSSB + mulch treatments. In 2019, 22 and 13 weed species occurred in pea and maize, respectively. The maximum pea pod yield was with intensive cropping followed by herbicide check in *Rabi* 2018-19. Herbicide check gave highest green cob yield (10323 kg/ha) of maize and was statistically equivalent to RSSB + hoeing (9208 kg/ha green cobs yield). Higher productivity (maize equivalent yield of 11420 kg/ha) was realized with the herbicide check which was at par with RSSB + hoeing (10160 kg/ha). The B:C followed the trend of intensive cropping > intercropping > herbicide check > RSSB + hoeing > RSSB + mulch.

Keywords: Cropping systems, Garlic, Maize, Non-chemical, Pea, Weeds, Weed management

INTRODUCTION

Maize is the third most important food crop after wheat and rice in India. About 80% of maize is cultivated during monsoon season particularly under rainfed conditions. Maize is one of the potential *Kharif* crops of the state and diversification within its cultivation for higher returns is possible through taking it up as green cob depending upon the market demand. In Himachal Pradesh, maize occupied an area of 286.78 thousand hectares producing around 725.55 thousand tons of grain with a productivity of 2.53 t/ha (Anonymous 2019-20). Being a hilly state and owing to unique agro-climatic conditions, most farmers are shifting to vegetables and fetching reasonably good prices. Organic management of maize-vegetable based system may further improve resource use efficiency, family employment and income, besides, achieving the wider national goals of sustainability and overall ecological health. However, weeds are a serious problem in maize, especially during *Kharif* season. They compete with maize for nutrient and causes yield loss up to 70% (Malviya and Singh 2007). Weed menace is one of the numerous constraints lowering the productivity of the cropping systems. Weeds grow rapidly in maize due to slower initial crop growth, wider row spacing and high fertilizers application, favourable soil moisture due to sowing of maize with the commencement of monsoon, and congenial temperature conditions (Sharma and Gautam 2010, Sinha *et al.* 2005). The rapid weed growth leads to severe crop weed competition which culminates in heavy reduction in growth and yield of the crop and lessens the profitability depending upon intensity, type of weed flora and nature of weed growth in relation to environmental conditions at or after sowing. Most of the hill and mountain regions of the Indian Himalayas are organic by default and have tremendous potential to emerge as major suppliers of organic products. Hand weeding, a commonly adopted method of weed control by farmers in the hill state. Many weed management tools used in organic production systems, like diversified rotation of crops, intensive tillage, and mulch, are soil friendly which reduce weed growth and prevent soil erosion (Bond and Lennartsson 1999, Saini *et al.* 2013).

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As both public demands for organic produce and the profile of organic farming have increased in recent years, the need has increased for wider range of organic weed control options including cultural methods of weed control such as the use of novel weed-suppressing cover crops, and the identification of specific crop traits for weed suppression (Rana *et al.* 2020, Saini *et al.* 2013). This study was aimed at assessing the effect of different non-chemical weed control measures on weeds and yield of sequentially grown garlic/garden pea and maize under organic farming conditions.

MATERIALS AND METHODS

Field experiments were carried out at Palampur, Himachal Pradesh located at 32°6´ N latitude, 76°3´ E longitude and 1290 m above mean sea level lying in North-West Himalaya in the Palam Valley of Kangra district of Himachal Pradesh, India during *Rabi*, 2017-18 to *Kharif*, 2019. The soil of the experimental field was silty clay loam in texture, low in organic carbon and available N, high in available P and medium in available K.

A randomized block design with three replications was used. Maize variety Kanchan Hybrid was sown during both the years and garlic variety Agrifound Parvati (G-313) and pea variety GS-10 were sown during the successive *Rabi* seasons. A manually operated wheel-hoe was used for hoeing. Lantana (*Lantana camara*) leaves from the nearby wasteland and forests were collected and used as a mulching material at the rate of 5 t/ha, which formed a thickness of about 5–6 cm on the soil surface. The treatment details are given in **Table 1**.

In stale seedbed plots, one irrigation was given 15 days prior to sowing to allow the germination of weeds, and the first flush of emerged weed seedlings were removed by disturbing the surface soil (up to 2 cm) at the time of crop sowing using a manually operated harrow. In case of raised stale seedbed plots, all conditions were like stale seedbed except that the seedbed was raised upto 12-15 cm height for providing proper drainage. Intercropping with soybean in case of maize and fenugreek in pea/garlic was done to check weed growth and get additional yields. The concept of rotating crops with different life cycles was used, as earlier in 2017 -18 *Rabi* season garlic was sown which was later rotated by pea. In case of intensive cropping, incorporation of pulse- soybean, oilseed- brown sarson, green manure crop- buckwheat were taken up. Pendimethalin (1.0 kg/ha) in pea and atrazine (0.75 kg/ha) in maize were used in herbicide check treatments.

Farmyard manure (0.86% N, 0.33% P, and 0.65% K) at the rate of 10 t/ha was applied 15 days before sowing in *Kharif* season and vermicompost at the rate of 15 t/ha during *Rabi* season was thoroughly incorporated into soil (based on availability). During *Rabi* (2017-18) maximum temperature ranged between 16.0 to 29.9°C. The minimum temperature ranged between 3.1 to 15.6°C. Total amount of rainfall received was 466.9 mm and 3132.4 mm in *Kharif* season. In *Kharif* season, the maximum temperature ranged between 20.0 to 30.6°C and minimum temperature ranged between 7.0 to 20.6°C. In 2018-19, the temperature during *Rabi* season ranged from 7.5°C to 25.5°C and during *Kharif* season, from 16.5°C to 35.5°C. A total of 639.6 mm rainfall occurred during the entire *Rabi* season and 1366.8 mm during entire *Kharif* cropping season. In each plot, data on weed count and dry weight were recorded, species-wise at monthly interval and at harvest from 50 × 50 cm quadrate at two places in each plot. The weed count and dry weight so obtained were converted to number and grams per square meter, respectively by multiplying the average count and dry weight of the weeds with factor 4. For weed shifts, the weed count data of the last year *Rabi* 2017-18 and *Kharif* 2018 was compared with the weed count data of 2018-19 *Rabi* and *Kharif* 2019 for the presence or absence of weed species. The yield of the

Table 1. The treatment details

Kharif (Maize green cob)	*Rabi* (Garlic/Peas)	Abbreviation
One hoeing followed by earthing up at knee high stage	Hoeing (twice) at 30 days after seeding (DAS) and 60 DAS	Hoeing
Stale seed bed (SSB) + hoeing + earthing up	SSB + hoeing + hand weeding (HW)	SSB + hoeing
Raised stale seed bed (RSSB)+ hoeing + earthing up	RSSB + hoeing + HW	RSSB + hoeing
Mulch (*Lantana*) 5t/ha	Mulch (*Lantana*) 5 t/ha	Mulch
SSB + mulch 5 t/ha	SSB + mulch 5 t/ha	SSB + mulch
RSSB + mulch 5 t/ha	RSSB + mulch 5 t/ha	RSSB + mulch
Intercropping (with soybean) + hoeing	Intercropping (with fenugreek) + hoeing	Intercropping
*Maize/soybean + hoeing+ earthing up	*Pea/sarson (mustard) + hoeing+ HW	Crop rotation
Maize + mulch + manual weeding *fb* autumn crop of sarson sag	Peas + mulch + manual weeding *fb* summer crop of buckwheat	Intensive cropping
Herbicide + HW	Herbicide + HW	Herbicide check

*Based on crop rotation, maize-peas in the first year and soybean-sarson (mustard) in the second year *i.e.* In *Kharif*, maize/soybean and in *Rabi* peas/ sarson alternatively; intensive cropping was based on intensive cropping; herbicide check was based on recommended dose of fertilizers and herbicides crops obtained from each net plot in the experiment was converted into gross returns in rupees based on prevailing market price of grains and straw. The treatment-wise net returns were obtained by subtracting the cost of cultivation from gross returns.

Benefit:cost ratio (B:C) was calculated by dividing net returns with cost of cultivation as follow:

$$\text{B/C ratio} = \frac{\text{Net returns from treatment (₹/ha)}}{\text{Cost of cultivation of the treatment (₹/ha)}}$$

Data on weeds were analyzed after square-root transformation $\sqrt{x+0.5}$ to account for the non-normality of distribution. All data were analyzed by ANOVA, and the least significant difference (LSD) values at 5% level of significance were calculated and used to test significant differences between treatment means.

RESULTS AND DISCUSSION

Effect on weeds

Weed flora of *Rabi* season: The weed flora composition in 2018-19 differed from that observed during 2017-18. The dominating weeds in garlic crop were *Phalaris minor* Retz. (17.1%), *Daucus carota* L. (14.1%), *Anagallis arvensis* L. (12.5%), *Poa annua* L. (8.9%), *Asphodelus tenuifolius* Cav. (8.9%), *Euphorbia helioscopia* L. (8.5%), *Vicia sativa* L. (7.2%), *Coronopus didymus* (L.) Sm. (4%) and *Tulipa altaica Pall. ex Spreng*. (3.6%). Weeds prevalent during *Rabi* 2017-18 and 2018-19 were *P. minor, A. arvensis, E. helioscopia, V. sativa, C. didymus* and *Tulipa altaica*. Some of the weed species such as *A. tenuifolius*, *Chenopodium murale* L., *Chenopodium album* L., *D. carota, Digitaria sanguinalis* (L.) Scop., *Medicago denticulata* Willd., *Panicum dichotomiflorum* Michx. and *Rumex obtusifolius* L. were absent in the pea crop during 2018-19. *P. minor, Stellaria media* (L.) *Vill., A. arvensis, Poa annua* L., *V. sativa, C. didymus, Allopecurus myosuroides* Huds. and *Artemisia ludoviciana* Nutt. were the major weeds infesting the pea crop. These results are in line with the findings of Mawalia *et al.* (2015), Singh and Angiras (2004). The studied organic systems had the highest population of perennial weeds which could be due to non-use of herbicides, low levels of disturbance of soil and a lower tillage level applied for seed-bed preparation. *Cyperus rotundus L., C benghalensis, P. annua* and *Euphorbia hirta L.* occurred during both the years. Alireza *et al.* in 2008 reported that in the organic systems perennial weeds accounted for 56 and 66% of the total weed population.

Species-wise weed density: Garlic crop was infested with many weeds owing to longer duration, slow initial growth, non-tillering/branching habit, space, canopy development and organic weed control practices. The density of *P. minor* was higher at 120 DAS and decreased in next month owing to manual removal to minimize the soil seed bank (**Table 2**). The density of it again increased due to the emergence of its new flush. SSB + mulch was statistically at par with intensive cropping. Maximum density of *A. arvensis* was recorded at 120 DAS and then decreased later due to manual removal to minimize addition to the seed bank.

Minimum density of *V. sativa* was observed in intensive cropping which was statistically at par with hoeing and SSB + mulch. The density of *Tulipa altaica* was highest at 180 DAS and decreased at harvest. The weed species such as *C. murale, C. album, D. sanguinalis, Galinsoga parviflora* Cav., *Lolium temulentum* L., *M. denticulata, P. dichotomiflorum, Plantago lanceolata* L., *Polygonum alatum D.Don, Ranunculus arvensis* L., *R. obtusifolius, S. media* and *Coriandrum tordylium* (Fenzl) Bornm. were present in very small number and hence were placed under other weeds category.

Table 2. Effect of treatments on species-wise weed density (no./m^2) during *Rabi* season

Treatment	*Phalaris minor*		*Vicia sativa*		*Anagallis arvensis*		*Tulipa altaica*		Other weeds	
	2017-18 (120 DAS)	2018-19 (90 DAS)	2017-18 (120 DAS)	2018-19 (90 DAS)	2017-18 (120 DAS)	2018-19 (120 DAS)	2017-18 (180 DAS)	2018-19 (30 DAS)	2017-18 (At harvest)	2018-19 (At harvest)
Hoeing	7.0(48.1)	2.3(6.7)	1.6(3.7)	3.8(14.0)	5.3(29.6)	0.7(0.0)	1.6(3.7)	2.6(8.0)	8.2(66.7)	8.7(79.1)
SSB + hoeing	6.4(40.7)	4.2(17.3)	2.5(7.4)	4.1(18.0)	5.5(29.6)	0.7(0.0)	0.7(0.0)	4.0(16.0)	8.0(63.0)	7.8(68.9)
RSSB + hoeing	6.7(44.4)	2.6(8.7)	3.4(11.1)	3.6(13.3)	5.1(25.9)	2.7(8.7)	1.6(3.7)	3.7(13.3)	5.1(25.9)	8.4(73.6)
Mulch	6.7(44.4)	4.1(16.7)	7.0(48.1)	3.1(12.7)	6.4(40.7)	3.1(9.3)	4.3(18.5)	4.0(16.0)	9.0(81.5)	7.6(58.7)
SSB + mulch	4.8(22.2)	3.5(13.3)	1.6(3.7)	4.1(17.3)	6.1(37.0)	6.0(36.0)	3.9(14.8)	3.9(14.7)	7.9(63.0)	10.3(105.8)
RSSB + mulch	5.5(29.6)	3.3(14.7)	3.4(11.1)	3.4(12.0)	8.0(63.0)	1.2(1.3)	0.7(0.0)	4.0(16.0)	6.4(40.7)	6.2(43.9)
Intercropping	7.7(59.3)	3.8(20.0)	4.3(18.5)	4.5(20.7)	5.1(25.9)	3.3(14.0)	3.4(11.1)	3.7(13.3)	6.0(37.0)	10.6(112.6)
Crop rotation*	6.1(37.0)	4.0(16.7)	5.1(25.9)	4.5(19.3)	5.3(29.6)	2.1(8.0)	2.5(7.4)	2.7(9.3)	8.2(66.7)	8.5(73.0)
Intensive cropping	5.1(25.9)	4.0(16.7)	0.7(0.0)	2.3(6.0)	6.4(40.7)	4.2(17.3)	5.5(29.6)	2.8(9.3)	10.2(103.7)	8.8(77.9)
Herbicide check	7.5(55.6)	3.0(8.7)	5.1(25.9)	2.9(10.7)	4.7(29.6)	0.7(0.0)	1.6(3.7)	3.7(13.3)	6.0(37.0)	7.0(50.9)
LSD (p=0.05)	0.7	NS	1.7	NS	NS	2.2	1.4	NS	1.1	NS

*Maize-pea and soybean-sarson alternatively. Values in parentheses are means of original values; Data transformed to square root transformation $\sqrt{x+0.5}$

Maize

Effect on weeds: During 2018 *Kharif* season, weeds that dominated the field were *C. benghalensis* (20.5%), *G. parviflora* (17.4%), *Ageratum* sp. (*Ageratum conyzoides* L. and *Ageratum houstonianum Mill.*) (10.7%), *Cyperus* sp. (9.5%), *D. sanguinalis* (7.3%), *Paspalum scrobiculatum* L. (6.6%), *P. alatum* (5.4%), *Phyllanthus niruri* L. (4.7%), *P. dichotomiflorum* (4.5%), *Bidens pilosa* L. (3.7%) and *Aeschynomene indica* L. (2.7%). *Alternanthera philoxeroides* L. also invaded the field but with lesser dominance (0.3%) and might be a potential future threat. In *Kharif* 2019, thirteen weed species were found in association with maize. *Echinochloa colona* (L.) Link (24%) was the most dominant weed followed by *Cyperus* sp. (22%), *C. benghalensis* (17%), *P. alatum* (11%), *G. parviflora* (11%) and *D. sanguinalis* (5%). The other weeds, *Eleusine indica* (L.) Gaertn., *Euphorbia geniculate Ortega, Ipomoea* sp., *Panicum distichum Lam.*, *Physalis minima* L., *A. indica* and *A. philoxeroides*, constituted 10% of the total weed flora. *C. benghalensis*, *D. sanguinalis*, *Cyperus* sp., *P. alatum*, *Panicum* sp. and *A. indica* invaded the field in both seasons. The changes in weed distribution might be due to changes in seed bank density and species composition which often occur when crop management practices and crop rotations are altered. The results are in line with the findings of Chopra and Angiras (2008), Chauhan *et al.* (2006).

Species-wise weed density (no./m²): Weeds data at their respective highest density are presented in **Table 3.** Weed management practices resulted in significant variations in the weed count of *P. alatum*, *D. sanguinalis* during the second year of study and in other weeds during the first year. Higher weed density was recorded during the second year in case of all the weed management practices. The distribution of weeds was random/sporadic rather than uniform and the count of rest of the weeds was not significantly affected inspite of large variations between the treatments. Chopra and Angiras (2008) reported that raised stale seed bed had significantly lowest weed density and biomass at 60 days after sowing and at harvest in maize crop. The density of *P. alatum* significantly varied among different weed control treatments during the second year. The density of this weed was maximum in RSSB + mulch followed by mulch, intensive cropping and hoeing treatments. In the beginning at juvenile stage, the species of *Cyperus* was unidentifiable and were taken together. However, at the reproductive stage, two species *Cyperus iria* L. and *C. esculentus* were observed. The count of *Cyperus* sp. (*C. iria* and *C. esculentus)* was in general higher at 60 DAS. Maximum count of *Cyperus* sp. was observed in

Table 3. Effect of treatments on species-wise weed density (no./m²) at maximum population stage of respective weed during *Kharif* season

Treatment	*Commelina benghalensis*		*Echinochloa colona*		*Polygonum alatum*		*Cyperus* sp.		*Digitaria sanguinalis*		Other weeds	
	2018 (30 DAS)	2019 (60 DAS)	2018 (60 DAS)	2019 (90 DAS)	2018 (60 DAS)	2019 (60 DAS)	2018 (60 DAS)	2019 (60 DAS)	2018 (60 DAS)	2019 (60 DAS)	2018 (At harvest)	2019 (60 DAS)
Hoeing	3.8 (18.5)	3.8 (18.7)	2.1 (7.4)	7.7 (66.7)	3.0 (11.1)	5.0 (24.7)	5.4 (29.6)	8.9 (125.3)	3.8 (18.5)	1.4 (2.7)	3.0 (11.1)	7.7 (87.3)
SSB + hoeing	7.4 (70.4)	7.5 (62.7)	2.1 (7.4)	3.5 (28.0)	2.7 (14.8)	0.7 0.0	6.2 (44.4)	0.7 (0.0)	4.4 (25.9)	0.7 (0.0)	2.5 (7.4)	4.2 (18.7)
RSSB + hoeing	6.3 (40.7)	5.6 (40.0)	2.1 (7.4)	4.8 (30.7)	2.4 (11.1)	1.6 (3.3)	0.7 (0.0)	5.8 (38.0)	3.9 (22.2)	3.8 (32.7)	0.7 (0.0)	7.0 (49.3)
Mulch	5.4 (29.6)	3.4 (14.7)	2.4 (11.1)	6.5 (81.3)	1.6 (3.7)	6.0 (38.0)	2.1 (7.4)	4.1 (24.7)	1.6 (3.7)	0.7 (0.0)	5.5 (29.6)	6.3 (42.0)
SSB + mulch	4.3 (25.9)	1.2 (1.3)	4.6 (29.6)	4.9 (33.3)	3.4 (14.8)	13.3 (6.0)	3.0 (11.1)	7.4 (57.3)	4.3 (18.5)	2.3 (6.0)	1.6 (3.7)	3.7 (13.3)
RSSB + mulch	6.6 (44.4)	5.1 (36.0)	2.4 (11.1)	9.0 (116.0)	0.7 (0.0)	9.2 (86.7)	3.4 (11.1)	9.1 (102.0)	3.8 (18.5)	2.5 (7.3)	0.7 (0.0)	2.8 (9.3)
Intercropping	3.4 (14.8)	5.7 (40.0)	2.7 (14.8)	3.1 (20.0)	2.1 (7.4)	4.8 (32.0)	3.8 (18.5)	9.5 (90.7)	1.6 (3.7)	2.1 (8.0)	4.3 (18.5)	3.6 (14.0)
Crop rotation*	3.4 (14.8)	6.7 (64.0)	2.7 (14.8)	5.1 (38.7)	2.4 (11.1)	2.7 (10.7)	4.1 (22.2)	1.8 (5.3)	2.4 (11.1)	8.8 (78.7)	4.7 (22.2)	5.3 (52.7)
Intensive cropping	4.3 (25.9)	7.2 (52.0)	4.1 (22.2)	4.5 (26.7)	4.1 (22.2)	5.6 (43.3)	2.1 (7.4)	11.3 (160.0)	1.6 (3.7)	0.7 (0.0)	0.7 (0.0)	3.8 (15.3)
Herbicide check	3.8 (18.5)	7.0 (61.3)	0.7 (0.0)	9.7 (94.7)	2.1 (7.4)	2.6 (13.3)	3.8 (18.5)	4.6 (50.7)	2.4 (11.1)	0.7 (0.0)	9.8 (96.3)	9.3 (86.7)
LSD (p=0.05)	NS	NS	NS	NS	NS	4.3	NS	NS	NS	3.7	1.8	NS

*Maize-garlic and soybean-peas alternatively; Data transformed to square root transformation $\sqrt{x+0.5}$, Values given in parentheses are the means of original values intensive cropping followed by hoeing, RSSB + mulch and intercropping. Least count of the species was seen in SSB + hoeing and crop rotation treatments. Density of this weed was initially low, then increased and later on showed a decline due to inter or intra-specific competition with broad-leaved weeds and maize crop for space, nutrients and light. Khan and Haq (2004) reported the similar trend in the population of this weed. The weed species such as *A. philoxeroides, E. indica, P. minima, A. indica, D. sanguinalis, E. helioscopia, Ipomea* sp. and *Panicum distichum* were present in lesser numbers, therefore, they were grouped under the category of other weeds.

Effect on yield attributes of garlic and peas in *Rabi*

The garlic plant population/m^2 was not significantly affected by weed control treatments (**Table 4**). Maximum number of bulbs/m^2 (45) was found under RSSB + hoeing being statistically at par with herbicide check, SSB + hoeing and hoeing. Maximum number of bulbs/m^2 under RSSB + hoeing was recorded which may be due to less competition by weeds. Minimum number of bulbs/m^2 was found in mulch. This may be due to the presence of higher number of weeds which competed with garlic for light, water, space and nutrients.

Maximum weight of bulb (g) was recorded in RSSB + hoeing which was statistically at par with herbicide check and SSB + hoeing. Thus, the treatments having lowest weed density were having better bulb weight due to less competition for growth factors among crop and weeds. In garlic, very close spacing and a shallow root system make mechanical method of weed control difficult and sometimes causes damage to developing bulbs (Lawande *et al.* 2009). Hence, the use of pendimethalin 2.5 kg/ha is recommended for getting higher garlic yield (Rahman *et al.* 2012). Therefore, garlic in herbicide check treatment showed significantly higher cloves per bulb and higher bulb weight compared to other treatments. Maximum number of cloves per bulb was recorded in RSSB + hoeing which was statistically at par with herbicide check, SSB + hoeing, hoeing and RSSB + mulch. Again, number of cloves/bulb was higher in the treatments having lowest crop weed competition. The highest garlic bulb yield in RSSB + hoeing was due to the low weed population and weed growth throughout the crop growth especially during earlier days which reduced crop-weed competition to greater extent and improved growth and development.

Yield attributes were adversely affected in plots where weed competition was high. This might be due to the shading effect caused by taller weeds like wild oat which reduced the availability of light for the photosynthesis. Akhter *et al.* (2009), Rana *et al.* (2004), Sajid *et al.* (2012) also reported decrease in yield attributes of field pea under the reduced photosynthetically active radiation. Plant population in general was significantly higher in treatments where hoeing was done (SSB + hoeing) and low in treatments (mulch) where mulching was done. However, hoeing alone and RSSB + hoeing was at par to herbicide check and intercropping treatments. This may have occurred because the mulch spread was quite thin to suppress weeds *i.e.* organic mulch (*Lantana camara* 5 t/ha), which allowed weed germination and enhanced weed growth by conserving soil moisture. Similar results were obtained by Mohler (1993). Highest number of pods were observed in herbicide check followed by RSSB + hoeing and SSB + hoeing. This was owed to effective weed control due to quick knockdown effect of the herbicide before the commencement of critical period of competition under the former treatment and elimination of one or two flushes before the sowing of the crop in the latter. Raised/stale seedbeds were as effective as that of herbicide check in improving the number of pods. In stale seedbeds, about 200/m^2

Table 4. Effect of weed control treatments on yield attributes of garlic and peas (*Rabi*)

Treatment	Effective plant population (no/m^2)		Cloves/bulb in a plant	Pods/ plant	Yield/plant (g)	
					Weight of onion bulbs	Peas pod yield/plant
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Hoeing	46.1	14.3	8.8	10.8	18.2	30.1
SSB + hoeing	47.8	15.3	8.9	12.5	21.8	34.9
RSSB + hoeing	47.8	14.8	9.4	13	22.8	36.3
Mulch	41.8	11.8	6.7	8.6	14.2	24.0
SSB + mulch	41.9	12.3	6.8	10.3	17.1	28.7
RSSB + mulch	47.2	12.3	8.5	12.5	19.0	34.9
Intercropping	45.5	13.3	7.7	10.9	17.8	30.4
Crop rotation*	-	-	-	-	-	-
Intensive cropping	44.1	12.8	7.0	10.6	17.2	29.6
Herbicide check	47.8	13.3	9.3	14.3	22.9	39.9
LSD (p=0.05)	NS	1.9	1.6	2.0	2.7	2.7

*Maize –pea and soybean- sarson alternatively weeds had germinated that were removed before crop sowing. The initial crop growth and development in stale seedbeds was, therefore, better due to absence of weed-crop competition. The superiority of RSSB in controlling weeds and increasing yield of pea has been reported by Tehria *et al.* (2015). SSB + hoeing followed by herbicide check and RSSB + hoeing showed higher pod weight per plot. This may be because of efficient weed management in these treatments due to lesser weed infestation and longer pods in these plots. The highest number of pods/plant were observed in herbicide check followed by RSSB + hoeing and SSB + hoeing. The pod yield was maximum with intensive cropping followed by herbicide check.

Effect on yield attributes of *Kharif* maize

All the yield attributes varied significantly during the second year (**Table 5**). The yield improved significantly in the second year. Maximum plant population/m^2 was recorded under RSSB + mulch at harvest during both the years. However, during 2018 RSSB + mulch was statistically at par with mulch, intercropping, intensive cropping and herbicide check whereas in the second year, mulch and intercropping didn't gave comparable yields. The higher plant population in this treatment could be attributed to improved weed control and comparatively more warming up of the seed bed and efficient drainage of the excess water. This improvement in crop growth and yield components was due to the consequence of lower crop weed competition, which shifted the balance in favour of crop in utilization of available resources (Saini *et al.* 2013, Sharma and Gautam 2010). Besides plant population, number of cobs/plant is the most important yield determination parameters. In the first year, number of cobs/plant in maize could not be significantly affected due to different weed management treatments. During the second year, weed control treatments resulted in significant variation in the number of cobs per plant. RSSB + hoeing and herbicide check each showed 1.9 cobs/plant. During 2018 hoeing was the next superior treatment. The rest of the treatments did not differ significantly in influencing average cob weight. Highest average cob weight was recorded with herbicide check followed by intercropping and RSSB + hoeing during 2019. This was because of efficient weed control in herbicide check and intercropping treatment which led to more uptake of nutrients by the crop and hence more cob weight.

Maize equivalent yield

The economic yields of crops (cob, greens, or pod) under different treatments were converted to their maize equivalents based on the prevailing market price of each product to facilitate the overall comparison among cultural weed management treatments (**Table 6**). During the first year, intercropping followed by intensive cropping gave the higher yields during *Rabi* season compared to other weed management treatments. It may be due to inclusion of more crops in the system. However during *Kharif* season in maize crop, higher yields were obtained in RSSB + mulch treatment followed by intensive cropping. Raised stale seedbed does not allows water to stagnate in the beds during heavy rains and thus might have resulted in higher yield. During the successive year intensive cropping where short duration crop of buckwheat greens was grown in the summer resulted in comparable maize equivalent yield as the herbicide check in the *Rabi* season. However, RSSB + hoeing, intercropping, RSSB + mulch and SSB + hoeing were equally good as the herbicide check. Similarly the additional crop of mustard greens after the harvest of maize in the autumn resulted in significantly higher maize equivalent yield under intensive cropping in the *Kharif* season. Herbicide check was the next superior treatment and RSSB + hoeing and intercropping were at par to it. Intensive cropping because of more yield from additional crops resulted in 10.4% higher overall system's maize cob equivalent yield than the herbicide check. RSSB + hoeing and intercropping resulted in comparable yields as herbicide check. The

Table 5. Effect of treatments on yield attributes of maize

Treatment	Effective plant population/m^2		Cobs/plant		Avg. wt./cob (g)	
	2018	2019	2018	2019	2018	2019
Hoeing	6.2	9.0	1.1	1.6	166.4	337.5
SSB + hoeing	6.2	8.5	1.0	1.3	163.2	314.4
RSSB + hoeing	6.7	10.4	1.2	1.9	178.3	410.7
Mulch	7.5	8.7	1.3	1.0	189.0	353.0
SSB + mulch	6.2	8.0	1.3	1.2	194.7	336.1
RSSB + mulch	7.7	9.0	1.4	1.2	203.4	337.5
Intercropping	7.3	8.0	1.0	1.1	153.4	430.6
Crop rotation*	-	-	-	-	-	-
Intensive cropping	7.0	9.7	1.2	1.3	179.5	388.2
Herbicide check	6.8	9.5	1.1	1.9	167.4	445.4
LSD (p=0.05)	0.7	1.4	NS	0.3	20.4	2.0

*Maize –pea and soybean- sarson alternatively

Table 6. Effect of treatments on Maize equivalent yield from 2017-19

Treatment	Maize equivalent yield (t/ha) 2017-18			Maize equivalent yield (t/ha) 2018-19		
	Rabi	*Kharif*	System's	*Rabi*	*Kharif*	System's
Hoeing	3.6	3.94	7.30	5.09	5.76	10.85
SSB + hoeing	3.12	2.55	5.67	12.27	5.78	18.05
RSSB + hoeing	4.26	3.96	8.22	13.55	9.21	22.75
Mulch	2.90	5.45	8.35	3.41	5.23	8.64
SSB + mulch	2.73	3.11	5.84	8.86	4.29	13.15
RSSB + mulch	3.96	6.94	10.90	12.48	6.51	18.99
Intercropping	5.04	4.92	9.96	12.75	9.33	22.08
Crop rotation	4.07	2.63	6.70	6.37	8.04	14.41
Intensive cropping	4.63	5.48	10.11	15.38	12.82	28.20
Herbicide check	4.25	4.25	8.51	15.23	10.32	25.55
LSD(p=0.05)	0.95	1.28	1.90	3.02	1.69	3.74

other treatments owing to lower crop yields were having low maize green cob equivalent yield as compared to the herbicide check. Hugar and Palled (2008) found that vegetable crops (cowpea, French-bean, coriander) intercropped with maize reduced the weed density and dry weight accumulation by weeds which resulted in higher maize equivalent yield at Dharwad, Karnataka.

Conclusion

In the organically managed production system, greater weeds floristic diversity was seen. Intensive cropping because of more yield from additional crops resulted in 10.4% higher overall system's maize cob equivalent yield than the herbicide check. RSSB + hoeing and intercropping resulted in comparable yields as herbicide check. The stale seedbed, hoeing and organic amendments application minimized the incidence and severity of weeds.

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