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Appraisal of different floor management practices for weed management in ber (*Zizyphus mauritiana* Lamk.) orchards

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ABSTRACT

Glyphosate was the commonly used herbicide in ber orchards in Punjab, India. This herbicide has been banned by State Government recently in the state. Therefore, there is a dire need to develop non- chemical approaches to check weeds in ber (*Zizyphus mauritiana* Lamk.) orchard. An experiment was conducted to study the influence of different orchard floor management practices on weed biomass, fruit yield and quality of ber at Punjab Agricultural University, Ludhiana (India). Different floor management practices, *viz*. mulching (rice straw, white polythene, black polythene), mechanical, glyphosate and weedy check were evaluated. Weed biomass recorded at monthly intervals from November to March under all floor management practices exhibited a significant reduction in weed growth as compared to the weedy check. White polythene mulch recorded higher weed growth with reduced weed biomass as compared to black polythene mulch due to the penetration of solar radiation leading to weed emergence and disintegration of white polythene sheet. The weed biomass in inter-cultivation and herbicide treatments was increased up to January, however, with second cultivation and herbicide spray, the growth of weeds under these treatments was checked up to February and again showed an increasing trend. Although, glyphosate suppressed the weeds and mechanical weeding reduced the weed density but the resurgence of weeds resulted in comparatively higher weed biomass, while, rice straw mulch exhibited promising results, with 87.1 and 91.2% reduction in total weed biomass during 1st and 2nd year, respectively. Application of rice straw mulch at 12.5 t/ha may help in weed management in ber orchards.

INTRODUCTION

Weeds are a major hindrance in agricultural production systems predominantly in horticultural crops. These unwanted plants strive for nutrition, moisture and light with main crops, besides, they also provide protection for various pests and diseases. In case of severe weed infestation in fields, the main crop is adversely affected in terms of plant growth, fruit yield and quality along with additional expenditure on the management of main crops. The profitability of arable cropping system can be reduced by 34 per cent due to weeds (Bullock and Murphy 1986). The reduction in the tree growth due to weeds ranges from 15 to 96 per cent (Atkinson and White 1980), about 35 per cent loss in yield as a result of the adverse impact on fruit quality was recorded. Further, the yield reduction can be up to 50per cent in the stone fruits (Hussein *et al.* 2016, Oerke 2006). So the yield losses caused by weeds surpass the losses from any other category of pests of agricultural production systems (Abouziena and Haggag 2016). Rao (2000) also reported a 45 per cent annual loss of agricultural produce due to weeds as compared to 30 per cent by insects, 20 per cent by diseases and 5% by other pests. The loss in fruit yield depends upon the weed flora and its density, fruit crop species, prevailing season *etc*. Therefore, the management of weeds in fruit crops is of utmost importance to prevent yield loss. Further integrated and environment-friendly approaches for weed management required to be standardized for different fruit crops (Abouziena *et al.* 2008).

Ber (*Zizyphus mauritiana* Lamk.) is one of the important fruit crops in North-West states of India. Presently, India is producing 2.68 million tonnes of ber fruits from 2.54 million hectare plantation (NHB 2015). In Punjab, this fruit crop has an area of 1516 hectare with a total production of 25432 MT with an average productivity of 16.8 tonnes per hectare (Anonnymous 2018). In Ber, profuse vegetative growth, flowering and fruit setting start after rainy season under North-West Indian conditions. Due to extensive vegetative growth of trees from October onwards, it becomes very difficult to manage weeds in ber orchards which compete for water and nutrients. Moreover, the fruit development of ber coincides with cold weather which contributes to physiological fruit drop resulting in lesser crop yield. Furthermore, most of the ber plantation in this region exists in sandy soils and water scarcity resulting in water stress during peak fruit development phase causing an increment in physiological fruit drop. Floor management in orchards is of utmost importance for the reduction in competition for moisture and nutrition by suppressing the weeds to maintain the soil temperature optimum enough to encourage root and shoot growth of fruit plants.

In tree fruit crops, the weeds can be managed by following different strategies, *viz*. chemical, mechanical, manual, mulching and biological methods etc. Though; the chemical weed control is highly effective and easy for weed management, however, this method has certain constraints as crop injury, soil and water residues, human health apprehension and development of resistance to herbicides (Pot *et al.* 2011). In present-day agriculture, manual weed management is very expensive and labour intensive. Mechanical weed control is an effective means for short term management of weeds, however, in established orchards, it is quite difficult and less efficient owing to spreading tree canopies as well as limited coverage by agricultural equipment and potential damage to root and shoots of fruit plants. Shallow ploughing results in less harm to the tree roots, the tillage of orchard floor using rotavator gives good results. In present days, most of the fruit growers rely upon mechanical weed management using adjustable rotavators as this machine not only performs shallow ploughing but also has wider coverage under tree canopies. Covering the soil surface with mulches is a safer method for weed management as compared to the application of herbicides (Ramakrishna *et al.* 2006). The organic mulches are easily available and cheap, while, the plastic mulches are costly for weed management in orchards. Moreover, the organic mulches are beneficial for plant growth and yield and fruit quality in addition to a highly effective method for weed repression (Childers *et al.* 1995). Faber *et al.* (2001) also recorded substantial weed reduction with organic mulches in citrus as well as in avocado over four years period. Mechanical and chemical weed management reduced the intensity of weeds but resurgence of weeds resulted in significantly higher weed biomass compared to rice straw mulch in guava orchard (Brar *et al.* 2017). The use of plough-disc has resulted in the death of 19per cent of the peach trees in a 4 years period (Taylor 1972) and in apples by 10per cent (Ricks *et al.* 1993), while there was no death with herbicides.

Rice-wheat is the dominant cropping system in Northwest India. So, the straw of rice and wheat is easily available. Therefore, it was hypothesised that different orchard floor management practices will reduce the weed population and affect fruit yield and quality of ber. Hence, to manage weed biomass, reduction in physiological fruit drop, higher fruit yield and better fruit quality, different orchard floor management practices were investigated in ber orchard during 2016-17 and 2017-18.

MATERIALS AND METHODS

The experiment was laid out in Punjab Agricultural University, Ludhiana (India) during 2016-17 and 2017-18 on 15-year old ber (*Zizyphus mauritiana* Lamk.) cv. Umran plants at 7.5 × 7.5 m spacing. Under various orchard floor management treatments, a different type of mulches, *viz*. rice straw mulch (PSM), white polythene mulch (WPM) and black polythene mulch (BPM) was applied under the canopies of the trees, standard glyphosate at 1.2 kg/ha, mechanical management and weedy. The rice straw mulch at the rate of 70 kg per tree providing 8-10 cm thick layer amounting to about 12.5 t/ha was applied by spreading it under the tree canopies. The black, as well as white polythene mulch of 38 µ thickness, was also applied in similar fashion. Post-emergence herbicide application was given during November when the weeds attained the height of 15-20 cm. The mechanical weeding was done using disc harrow at the same time and the basins around the tree trunks were cleaned manually and these treatments were again repeated in January. The treatments were initiated in October after cleaning the orchard and application of recommended doses of inorganic fertilizers. The experiment was replicated thrice.

The weed density was estimated by using quadrat (1.0 × 1.0 m) placed randomly in all the replications. The grasses, sedges and broadleaf weeds were counted separately at a monthly interval from November to March. The weed biomass was recorded by drying the weeds at a monthly interval in a hot air oven at 65^{0}C temperature for 3-4 days. The weeds were removed at ground level after placing the quadrate at random places under for dry weight. The dry weight of weeds was expressed in g/m. The data of the actual number of weeds were transformed by square root transformation ($\sqrt{x+1}$) for statistical analysis. Statistical analysis of the data was done using CPCS1 software and comparisons were made at 5 per cent level of significance.

RESULTS AND DISCUSSION

Weed flora

The weed flora noted during the study comprised of mainly grasses (*Cynodon dactylon, Sorghum halepense, Panicum maximum*), sedges (*Cyperus rotundus, Cyperus compressus*) and Broadleaf weeds (*Cannabis sativa, Parthenium hysterophorus, Chenopodium album, Medicago denticulate, Rumex dentatus, Fumaria parviflora, Anagallis arvensis, Coronopus didymus* and *Malva neglecta)*.

Weed biomass

Biomass of broad-leaf weeds (BLW) and grass weeds were significantly less under all the treatments as compared to weedy check (**Table 1 and 2 and Figure 2**). After putting mulch in the field and other floor management treatments in the middle of October during 1st year, weeds started emerging at the end of October. Moreover, there was profuse weed growth in the weedy plot (70 g/m^2) up to 3rd week of November, however, under PSM it was only 7.0 g/m^2 followed by 17 g/m^2 in cultivated field and 12 g/m^2 under herbicide treatment. The weeds flourished up to February under WPM and weedy plots throughout the study period, however, in case of herbicidal and inter-cultivation treatments, the weed growth was suppressed in February with the second spray of herbicide and inter-cultivation done in 3rd week of January. In March, there were only 16 g/m^2 weed biomass under PSM as compared to 177 g/m^2 in weedy plots. No weed growth was recorded throughout the season under BPM. Rice straw mulch was found to be effective among all floor management treatments for weed management, only 9.0 per cent weed growth was recorded as compared to the weedy check. Similarly, under inter-cultivation and chemical weed management, weed growth remained under check and it was only 26.3 and 20.4per cent of weedy fields under both the treatments, respectively. White polythene mulch was not effective due to disintegration of mulch sheet which might be due to the direct entrance of solar

Table 1. Effect of different orchard management treatments on broad-leaf weed biomass (g/m^2) in ber (Nov to Mar, 2016-17 and 2017-18).

Treatment	November		December		January		February		March	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
PSM	1.34 (1)	1.38 (1)	1.49 (1)	1.44 (1)	1.81 (2)	1.62 (2)	2.49 (2)	2.00 (3)	2.12 (3)	1.94 (3)
WPM	1.85 (2)	3.36 (10)	2.37 (5)	3.78 (13)	2.72 (6)	3.95 (14)	5.86 (16)	3.33 (10)	4.46 (19)	4.46 (19)
BPM	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
Inter-Cultivation	2.63 (6)	2.70 (6)	3.07 (8)	3.61 (12)	4.40 (18)	4.31 (18)	4.50 (19)	4.29(17)	4.91 (23)	4.84 (14)
Chemical	2.41(5)	2.37 (5)	2.79 (7)	2.95 (8)	2.88 (7)	3.33 (10)	3.62 (12)	3.32 (10)	4.15 (16)	4.15 (10)
Control (weedy)	3.35 (10)	3.64 (12)	3.93 (14)	3.98 (15)	4.12 (16)	4.55 (20)	4.89 (23)	4.51 (19)	5.38 (28)	5.15 (25)
LSD (p=0.05)	0.18	0.17	0.10	0.19	0.11	0.19	0.14	0.12	2.02	0.21

*Data is subjected to square root transformed. Original figures are in bracket; PSM: Paddy straw much; WPM: White polythene mulch; BPM: Black polythene mulch

Table 2. Effect of different orchard management treatments on grass weed biomass (g/m^2) in ber orchard (Nov to Mar, 2016-17 and 2017-18)

Treatment	November		December		January		February		March	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
PSM	2.61 (6)	2.32 (4)	2.65 (6)	2.47 (5)	3.19 (9)	2.84 (7)	3.52(11)	3.06 (8)	3.73 (13)	3.24 (10)
WPM	4.70(21)	5.58(30)	5.09(25)	5.60(30)	5.54(30)	6.16(37)	6.27(38)	6.93 (47)	7.78 (59)	7.78 (59)
BPM	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	1.00(0)	1.00 (0)
Inter-Cultivation	3.45(11)	3.61(12)	3.87(14)	4.00(15)	4.66(21)	4.92(23)	5.05(24)	5.53(30)	8.97(79)	8.63(73)
Chemical	2.78 (7)	2.78 (7)	3.98(15)	3.95(15)	4.90(23)	4.91(23)	5.27(27)	5.50 (29)	6.02(35)	6.02 (35)
Control (weedy)	7.80(60)	7.56(56)	8.07(64)	8.31(68)	9.15(83)	9.27(85)	9.56(90)	10.43(108)	12.23(149)	11.27 (126)
LSD (p=0.05)	0.26	0.23	0.20	0.28	0.22	0.18	0.14	0.42	0.20	0.20

*Data is subjected to square root transformed. Original figures are in bracket; PSM: Paddy straw much; WPM: White polythene mulch; BPM: Black polythene mulch

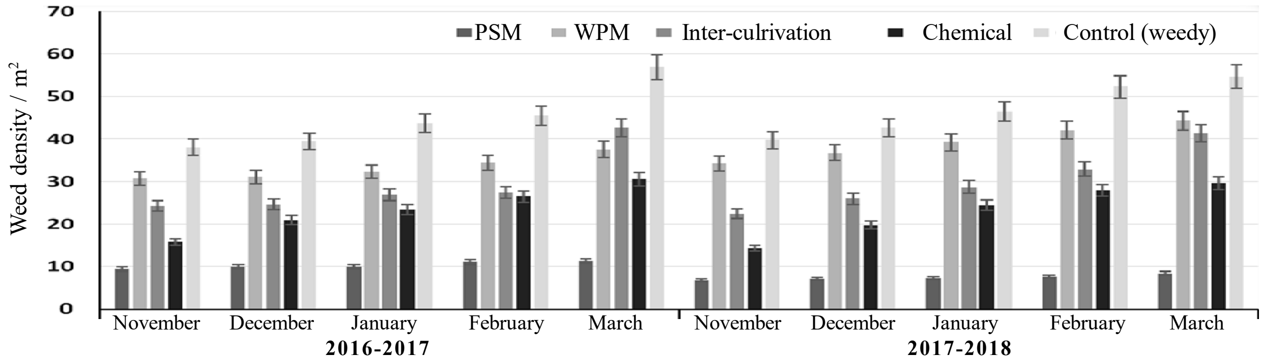

Figure 1. Weed density (no. of weeds/m^2) under different orchard floor management treatments from November to March (2016-17and 2017-18). Vertical bars represents mean S.E.

radiation through it leading to germination of weeds which ruptured the polythene sheet and emerged on the surface. Lesser biomass of sedges and grass weeds was recorded as compared to broad-leaf weeds throughout the season.

During the second year, the weed pressure under all treatments was comparatively less than the first year (**Table 2**). The weed biomass was significantly less under all treatments as compared to weedy check. This could be due to less weed density recorded in these treatments because of less light transmission under the mulches leading to reduced germination of weed seeds; hence less weed seed bank as reported by Golzardi *et al.* 2015. Weed biomass was only 5 g/m^2 under PSM as compared to 68 g/m^2 in weedy plots during November. Rice straw mulch exhibited a significant reduction in weed biomass in guava orchard (Brar *et al.* 2017). Rice straw mulch gave 85-98 per cent control of weeds in papaya (Hassan and El-Shammaa 2001) and 89 to 95per cent, in olive groves (Huqi *et al.* 2009).

The weed biomass in the same month under WPM, inter-cultivation and herbicide treatment was 40, 18 and 12 g/m^2, respectively. Manual weeding and herbicide combination of 0.5 kg glyphosate + 1.0 kg 2,4-D per hectare was quite effective in providing weed control in guava orchard (Maji *et al.* 2008). Bajwa *et al.* (1993) also opined the application of glyphosate to be effective in killing weeds in ber. Mechanical weed management is the pertinent method for suppression of weeds when the use of chemicals is not desirable (Chicouene 2007). The increment in weed growth was observed under all treatments up to March except in inter-cultivation and herbicide treatments, whereas, other treatments resulted in checking of weed growth in the month of February. There were only 12, 51, and 78 and 95 g/m^2 weed biomass under PSM, chemical, WPM and inter-cultivation respectively, up to March. Among all treatments, the proportion of grassy weeds was less than broad-leaf weeds during both the years. The increase in weed growth after February was due to irrigation to the ber orchard coupled with the rise in temperature after cold winters. Cumulative weed biomass was significantly higher under weedy check, while it was only 9.0% of weedy check under PSM (**Figure 2**). About 85- 98 per cent weed control was reported by covering the soil with two layers of cattail or rice straw mulch under mandarin trees (Abouziena *et al.* 2008). Cumulative weed biomass under chemical treatment, inter-cultivation and WPM was 20.4, 26.3 and 45.2% in weedy check, respectively. Different types of plastic mulches have specific properties of optimization of soil microclimate, soil moisture conservation, weed management etc. White or transparent mulch had a slight effect on weeds, while, weed emergence was quite less under coloured mulches such as brown, black, blue or double coloured films (Bond and Grundy 2001). Abouziena *et al.* (2008) obtained the effective control of weeds with the plastic mulch (200 or 150 µm) and three mulch layers of rice straw. Black polyethene mulch gave maximum weed control efficacy as compared to green, blue, yellow and white mulching in apple orchard (El-Metwally and Hafez 2007).

Weed density

The average weeds density after one month of treatments increased instantly under weedy check with 38.9 weeds/m^2 of different species followed by 37.6/m^2 under WPM which was ripped due to excessive weed growth beneath the polythene sheet (**Figure 1**). The minimum number of weeds (8.1/m^2) have emerged under PSM followed by chemical (15/m^2) and mechanical (23.3/m^2) methods of orchard management, although it was nil under BPM. During the second month, the weed density was slightly increased under all treatments except under chemical treatment where the increment in the number of weeds was more than 25%. Similarly, in following months, the weed density exhibit showed an increased trend up to the month of

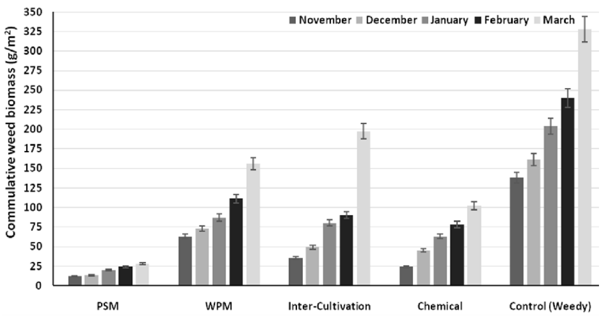

Figure 2. Cumulative weed biomass (g/m²) under different orchard floor management treatments from November to March (2016-17 and 2017-18). Vertical bars represents mean S.E.

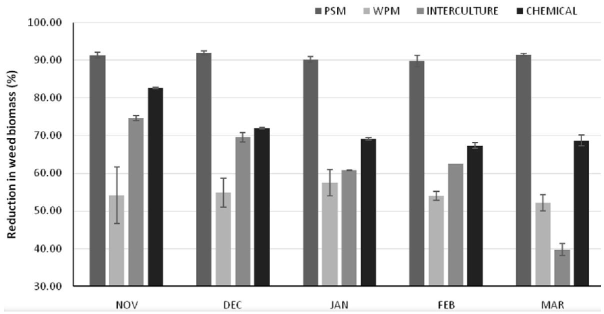

Figure 3. Reduction in weed biomass (g/m²) under different orchard floor management treatments as compared to weedy check. Vertical bars represents mean S.E..

March. In the last month of observations, the number of weeds per square meter area was maximum (55.8) in weedy check, followed by under WPM (46.0), under inter-cultivation (41.9) and herbicide treatment (30.1). Rice straw mulch consistently suppressed the weed population during the study period with minimum weed population of 9.9/m². The overall slow increase in weed population under all treatments and weedy check was due to prevailing low-temperature conditions under North-West India during the period of study. Although, the weed density increased slowly, but the biomass increased at a faster rate due to the growth and development of weeds that emerged during the initial months.

The increased weed population under all treatments was observed under all treatments from November to February at slow pace probably due to dip in atmospheric temperature. Increase in weed density due to reduced herbicide effectiveness under chemical treatments, loosening of soil surface followed by application of irrigation water and occurrence of rainfall under mechanical treatment, ripping of WPM. However, after February, the weed density and biomass was increased at comparatively faster rate due to increasing atmospheric temperature.

The weed density under various treatments confirmed the effectiveness of all the floor management treatments particularly BPM and PSM for weed suppression. The plastic and organic mulches cause hindrance in weed emergence by restricting the light, thereby, suppressing weed growth. Black plastic mulches restrict the water and light penetration on the soil surface to provide high weed control efficiency. Weed reduction was also recorded with BPM and grass mulching in drip irrigated 'Nagpur mandarin' (Shirgure *et al.* 2013). While, white and green coverings had little effect on preventing weeds emerging (Bond *et al.* 2003).

Yield and economics: The data in **Table 3** revealed that the cost on rice straw mulching was only ₹ 2.5/m² area as compared to ₹ 16/- and ₹ 17.5/- in case of white and black polythene mulches, respectively. Although, the cost on the management of weeds through inter-cultivation and chemical means was only ₹ 2.5 and ₹ 2.0 per square meter area but, the fruit yield was significantly less than PSM under these treatments which renders them uneconomical. With rice straw mulching higher fruit yield and low cost on mulching resulted net gain of ₹ 22167/- and ₹ 24980/- per hectare area during first and second year of investigations over the control, respectively.

The inhibitory effect of organic mulch on weeds may be due to both the physical (the reduced passage of solar radiation and temperature range on soil

Table 3. Economic aspects of mulching in ber orchards

Treatment	Yield/tree (kg)		Average rate (₹/kg)	Gross income/ha (x10³/₹)		Cost of mulching (₹)		Net income/ha (x10³/₹)		Increase or decrease in income over control (₹)	
	2017	2018		2017	2018	(m²)	(x10³ /ha)	2017	2018	2017	2018
Paddy straw mulch (PSM)	108.68	123.8	12.5	244.53	278.55	2.5	17.50	227.03	261.05	22167	24980
White polythene mulch (WPM)	102.61	106.83	12.5	230.87	240.37	16.0	112.00	118.87	128.37	-85990	-107703
Black polythene mulch (BPM)	106.58	120.31	12.5	239.80	270.70	17.5	122.50	117.30	148.20	-87557	-87872
Inter-cultivation	99.6	113.16	12.5	224.10	254.61	2.5	17.50	206.60	237.11	1737	1040
Chemical	100.44	110.56	12.5	225.99	248.76	2.0	14.00	211.99	234.76	7127	-1310
Control	91.05	104.92	12.5	204.86	236.07	0.0	-	204.86	236.07	-	-
LSD (p=0.05)	5.85	7.1	-	-	-	-	-	-	-	-	-

superficial layer) effect of emergence suppression and the possible chemical effects arising from allele chemicals released by straw that may have contributed to emergence reduction (Oliveira *et al.*2014). In addition to this, allelopathic interaction and chemical/biological influences of mulching on pH and nutrients dynamics in the surface soil also contributes towards growth of herbs under tree canopies. Hence, it may be concluded that the PSM has potential to check weed population in ber orchards and to improve soil health as organic mulches, not only increase soil fertility significantly but improve soil physical characters (0–10 cm depth) compared to other mulches also (Qu *et al.* 2019). Furthermore, it fits scrupulously with 'ber' crop and rice straw availability *i.e.* PSM is applied after application of second split of inorganic fertilizer in the month of October and at the same time there is ample availability of rice straw as after mid-October, rice is generally harvested under Punjab conditions.

It is concluded that rice straw mulch at 12.5 t/ha recorded the highest ber yield and may be recommended to the farmer's for effective control of weeds in ber orchards.

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