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Effect of weed management strategies on weed count and yield attributes of apple (*Malus* × *Domestica)* under high density orchard system

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Abstract
A field experiment was conducted during 2018 to assess the effect of different weed management strategies on weed count and yield attributes of apple under high density orchard system. The said investigation was carried out in experimental fields of Division of Fruit Science, SKUAST, Kashmir. One year old trees of exotic apple cv. "Elstar" grafted on M-9 T337 rootstock, introduced from Holland in March 2017, were selected for experimentation. Thirteen selected treatments were laid in randomized complete block design, with each treatment replicated thrice. The results revealed that the use of the combination of pre and post emergent herbicide was significantly effective in controlling weeds. Minimum weed count (0.25) was found under T_{12} (Oxyfluorfen followed by Glufosinate ammonium). Maximum incidence of weeds was recorded under unweeded control. Furthermore significant influence of different weed management strategies was observed on initial and final fruit set in high density apple trees. Maximum final fruit retention was obtained under paddy straw mulch. The highest fruit yield per tree was recorded under T_{12} (Oxyfluorfen followed by Glufosinate ammonium) which was statistically at par with T_5 (paddy straw mulch). Minimum final fruit retention, fruit yield and yield efficiency was recorded under control indicating that weed management strategies are very much essential under high density orchard system for obtaining higher yield.

Keywords: Fruit set, oxyfluorfen, Glufosinate ammonium, paddy straw

Introduction
Apple (*Malus* × *domestica* Borkh) is one of the most ubiquitous and well-adapted species of temperate fruit of the world grown particularly in North-Western Himalayas at an elevation range of 1500-2700 m amsl. It is known as the king of temperate fruits and is fourth among the most widely produced fruits in the world after banana, orange and grapes. Jammu and Kashmir with the area of 1,64,742 hectares and production of 18,82,319 MT (2018-19) is leading in both area and production in the country. J&K has remained the leading apple producer accounting for almost 54% of area and 79% of the total production in the country (2018-19). Yield of apple has shown an increase from 2.62 to 11.45 MT/ha (Department of Horticulture J & K, 1975-2018) [7]. The productivity of apple in India is very low as compared to developed countries like China, Italy, Spain, USA etc (FAOSTAT, 2017) [8]. The high-density planting system (HDP) is now being conceived as an alternative production system having a potential for improving productivity, increasing yield efficiency, reducing input cost, minimizing risks and maximizing returns.
Weed management in high density orchards is a critical component for successful crop production (Atay *et al*., 2017) [2]. The primary goal of weed management is to optimize yield by minimizing the weed competition (Merwin, 2003) [18]. Kalita and Bhattacharya (1995) [14] reported that uncontrolled weed can cause significant reduction in yield and fruit quality and decrease yield/ tree by 62% compared to control. Also because of shallow root system in HDPs the weeds cause heavy losses by competing with the main crop for water, nutrients and also provide potential breeding niche for various insects/pests and diseases.

Thus one of the disquieting challenges in fruit production in high density orchards is weed management that can be managed through various management strategies like manual, mechanical, cultural, biological and chemical control (Hira *et al.*, 2004) [10]. Since different control measures can be taken up to deal with the weed problem but the key to effective management is to apply the right material at appropriate time. So present study was carried out with the objective of studying the effect of different weed management strategies on weed population and yield attributes of apple (cv. Elstar), under high density orchard system.

Material and Method

The experiment was conducted in the Experimental fields of Division of Fruit Science, Sher-e-Kashmir University of Agricultural Science & Technology of Kashmir, Shalimar, Srinagar, Jammu & Kashmir during the year 2018. One year old trees of exotic apple cv. "Elstar" grafted on M-9 T337 rootstock, spaced at 1 x 3 m (3333 trees /Ha), introduced by SKUAST-Kashmir from Holland in March 2017 were selected for experimentation. The trees of uniform size, vigour and bearing capacity were selected for experiment. The experiment was laid out in Randomized complete block design (RCBD) comprising 13 treatments and 3 replications. The treatments included: T_1 -Farmer's Practice (Hoeing at 45 days interval, 3 hoeing's starting from last week of March), T_2 - Black polyethylene mulch (Punched) - 200µ, T_3 - Black polyethylene mulch (Unpunched) - 200 µ, T_4 - Bi-Colour polyethylene mulch - 200 µ, T_5- Paddy Straw mulch - 10cm thickness, T_6 - Forest Litter (Pine Needles) - 10cm thickness, T_7 - Chopped lawn grass - 5cm thickness, T_8 - Oxyfluorfen @ 0.5 L ha^{-1} (Pre-emergence herbicide), T_9- Glyphosate @ 2.0 L ha^{-1} (Post-emergence), T_{10} - Glufosinate ammonium @ 0.84 Kg ha^{-1} (Post-emergence), T_{11} - Oxyfluorfen @ 0.5 L ha^{-1} (Pre-emergence herbicide) followed by Glyphosate @ 2.0 L ha^{-1} (Post-emergence), T_{12} - Oxyfluorfen @ 0.5 L ha^{-1} (Pre-emergence herbicide) followed by Glufosinate ammonium @ 0.84 Kg ha^{-1} (Post-emergence) and T_{13} - No Weeding (Control). The application of organic as well as inorganic mulches were done during last week of March. Oxyflourfen was applied as pre-emergence herbicide during the first week of March, whereas, glyphosate and glufosinate ammonium were applied as post-emergent herbicide during mid of June. Quadrant of 30cm x 30cm (0.9m^2) was randomly thrown in each plot. Monocot and dicot weeds under the quadrant were counted. Initial reading was taken on 1st May and subsequent readings at 30 days intervals. Final reading was recorded at the time of harvesting. The weed population was expressed as average number per 0.9 m^2 and the data were subjected to statistical analysis after using square root transformation. The initial fruit set and final fruit retention was calculated by using the formula suggested by Westwood (1978) [27] and expressed as:

$$\text{Per cent fruit set} = \frac{\text{No. of fruits at pea stage}}{\text{No. of flowers}} \times 100$$

$$\text{Fruit retention (\%)} = \frac{\text{No. of fruits at harvest}}{\text{No. of fruit lets at pea stage}} \times 100$$

Yield efficiency efficiency of the tree was calculated by dividing yield per tree with trunk cross sectional area and expressed as Kg cm^{-1}. The statistical analysis was carried out based on the procedure given by Gomez and Gomez (1984) [9]. The treatment effects were tested at 5 percent level of significance.

Results and Discussion

Weed population

The mulches and herbicides were observed to have a significant influence on weed population on all sampling days. Perusal of the data presented in Table 1 reveals that different weed management strategies had a significant influence on weed population during. After 120 days of treatment, there was lowest weed population (0.25 m^{-2}) under T_{12} (Oxyfluorfen followed by Glufosinate ammonium) which was statistically at par with T_{11} (Oxyfluorfen followed by Glyphosate) followed by T_3 (Unpunched black polyethylene mulch) and T_4 (Bi-Colour polyethylene mulch). The highest number (27.17 m^{-2}) of weed population was recorded under control (T_{13}) followed by 19.50 m^{-2} under T_1 (Farmer's Practice). Among dates, total weed population in high density apple orchard was minimum (2.29 m^{-2}) on 1st May and maximum (3.28m^{-2}) on 1st August. The treatment T_{12} showed 47.9% and 40.45% superiority over treatment T_{13} (unweeded plot) and T_1 (farmer's practice) respectively in controlling weed population. The pre-emergent herbicide (Oxyfluorfen) used in the present investigation was contact and kills the weeds through the contact action and membrane disruption. This herbicide causes inhibition of both electron transport chain and ATP systhesis. The post emergent herbicides (Glyphosate and Glufosinate ammonium) used were systemic in nature. Glyphosate is ESP (5-enolpyruvylshikimate 3-phosphate) synthase inhibitor which in turn inhibits protein synthesis. Thus causing cessation of the growth and degradation of plant tissues due to lack of proteins. Glufosinate ammonium is glutamine synthase inhibitor (one of the most important enzyme in nitrogen metabolism), accumulates ammonium ions and inhibits photosynthesis. Reduced weed population under mulching treatments may be attributed to the absence of sunlight coupled with the physical barrier provided by bi-colour and black polythene mulch.

The significant control of weeds by herbicides and mulches observed in the present studies were also in conformity with the findings of several earlier researchers (Sharma, 2003; Chatha and Chanana, 2007; Dalal *et al.*, 2011; Kaith and Bhardwaj, 2011; Singh and Bal, 2013 and Shankar *et al.*, 2014) [23, 5, 6, 13, 24, 22]. Herbicides are the most important weed control tools for alleviating the infestation of weeds and getting higher yields (Ashiq *et al.*, 2007) [1] and also seem to be indispensible and have proved to be efficient for weed control (Kahramanoglu and Uygur, 2010) [12]. Buskiene *et al.*, (2006) [4] also reported that use of herbicide (glufosinate ammonium) killed 80.4-95.33% of weeds.

Yield parameters

Different weed management practices were observed to have a significant effect on initial fruit set, final fruit retention, fruit yield and yield efficiency of apple under high density orchard system. The use of organic mulches significantly increased the initial as well as final fruit set. Among different treatments, maximum initial fruit set (93.07%) was found under T_5 (Paddy Straw mulch), which was statistically at par with T_6 (Forest Litter) (92.70%), followed by 91.73% under T_7 (Chopped lawn grass) and T_{12} (Oxyfluorfen followed by Glufosinate ammonium) (90.70%). Maximum final fruit retention (88.10%) was obtained under paddy straw mulch (T_5) which was statistically at par with treatments T_6 (Forest Litter) (87.93%), T_{12} (Oxyfluorfen followed by Glufosinate

ammonium) (87.80%) and T_7 (Chopped lawn grass) (87.33%). This positive response of organic mulching treatment may be due to increase availability of soil moisture and nutrients, favourable soil temperature and lower weed population which in turn increased the flower primordial carbohydrates and nutrients essential to promote flowering and fruit set in plants. These results are in conformity with the finding of Kumar *et al.*, (2008) [17], Negi (2015) [19] and Hussain *et al.*, (2017) [11]. Similar result was also reported by Pande *et al.* (2005) [20] who reported that the final fruit retention and subsequent yields were highest from the tree receiving the dry grass mulch. The herbicidal application maintained the weed free conditions and allowed the plants to exploit the available soil resources resulting into higher growth and vigour of plants, which consequently lead to higher production of flowers and better fruit set. Herbicidal treatments have been reported to increase the cropping of stone and pome fruits by many workers (Welker and Glenn, 1985 and 1990 and Raese, 1990) [26, 27, 21]. Minimum initial fruit set (82.57%) and final fruit retention (70.51%) was recorded under unweeded control due to decreased soil moisture and nutrient loses due to high weed growth ultimately resulting in higher fruit drop.

Fruit yield per tree (9.16 Kg tree^{-1}), yield per hectare (30.53 tonnes ha^{-1}) and yield efficiency (1.00 Kg cm^{-2}) were maximum under T_{12} (Oxyfluorfen followed by Glufosinate ammonium) which was followed by T_5 (Paddy straw mulch). However, these parameters were minimum under unweeded control (T_{13}). The increase in fruit yield per plant was directly related to the reduced crop-weed competition which conserved the soil nutrient and soil water contents and ultimately favoured better yield performance under different weed control treatments. An increase in yield following the application of herbicides is related to floor vegetation suppression by herbicides for a long time and the increased availability of nutrients and moisture. Moreover, the continuous applications of herbicides in the overall weed free environment helps to fully exploited the available soil nutrients and moisture resulting in early growth and vigour of trees which consequently lead to the production of extensive branch system and spur production capable of bearing a large number of fruit crops. The efficiency of herbicides in relation to improvement of crop yield has been demonstrated by several workers in different fruit crops (Khokhar *et al.*, 2001; Sharma, 2003; Bhat, 2004 and Kaur and Kaundal, 2013) [16, 23, 3, 15].

Table 1: Effect of weed management strategies on weed population of apple cv. Elstar under high density orchard system

Days after reference date (1st April) / Treatments	Weed population				
	30	60	90	120	Mean
T_1: Farmer's Practice (Hoeing at 45 days interval, 3 hoeing's starting from last week of March)	11.00 (3.46)	15.67 (4.08)	19.67 (4.55)	31.67 (5.72)	19.50 (4.45)
T_2: Black polyethylene mulch (Punched) - 200µ	1.33 (1.52)	3.67 (2.16)	4.33 (2.31)	5.67 (2.58)	3.75 (2.14)
T_3: Black polyethylene mulch (Unpunched) - 200 µ	1.00 (1.38)	1.33 (1.49)	1.67 (1.58)	3.33 (2.07)	1.83 (1.63)
T_4: Bi-Colour polyethylene mulch - 200 µ	1.00 (1.38)	1.33 (1.52)	1.67 (1.63)	3.33 (2.08)	1.83 (1.65)
T_5: Paddy Straw mulch - 10cm thickness	1.00 (1.38)	4.00 (2.23)	8.67 (3.11)	14.67 (3.96)	7.08 (2.67)
T_6: Forest Litter (Pine Needles) - 10cm thickness	3.67 (2.16)	5.67 (2.58)	11.00 (3.46)	19.67 (4.55)	10.00 (3.19)
T_7: Chopped lawn grass - 5cm thickness	8.67 (3.11)	10.67 (3.41)	18.33 (4.39)	27.33 (5.32)	16.25 (4.06)
T_8: Oxyfluorfen @ 0.5 L ha^{-1} (Pre-emergence herbicide)	0.00 (1.00)	0.67 (1.28)	4.67 (2.38)	7.67 (2.94)	3.42 (1.89)
T_9: Glyphosate @ 2.0 L ha^{-1} (Post-emergence)	16.00 (4.12)	19.00 (4.47)	1.67 (1.63)	3.67 (2.16)	10.25 (3.13)
T_{10}: Glufosinate ammonium @ 0.84 Kg ha^{-1} (Post-emergence)	15.67 (4.08)	18.67 (4.43)	1.33 (1.52)	3.33 (2.08)	10.00 (3.09)
T_{11}: Oxyfluorfen @ 0.5 L ha^{-1} (Pre-emergence herbicide) followed by Glyphosate @ 2.0 L ha^{-1} (Post-emergence)	0.00 (1.00)	0.67 (1.24)	0.33 (1.14)	1.33 (1.49)	0.58 (1.22)
T_{12}: Oxyfluorfen @ 0.5 L ha^{-1} (Pre-emergence herbicide) followed by Glufosinate ammonium @ 0.84 Kg ha^{-1} (Post-emergence)	0.00 (1.00)	0.67 (1.28)	0.00 (1.00)	0.33 (1.14)	0.25 (1.10)
T_{13}: No Weeding (Control)	16.00 (4.12)	20.66 (4.65)	31.33 (5.69)	41.33 (6.51)	27.17 (5.27)
Mean	5.85 (2.29)	8.03 (2.67)	8.05 (2.64)	12.56 (3.28)	

C.D (≤0.05)
Treatments : 0.177
Days : 0.098
Treatment x Days : 0.354 (Note: Values under parentheses are square root transformed values.)

Table 2: Effect of weed management strategies on yield characteristics of apple cv. Elstar under high density orchard system

Treatments	Initial fruit set (%)	Final fruit retention (%)	Fruit yield per tree (Kg tree^{-1})	Fruit yield per hectare (Tonnes/ ha)	Yield efficiency (Kg cm^{-2})
T_1: Farmer's Practice (Hoeing at 45 days interval, 3 hoeing's starting from last week of March)	84.23	74.22	6.65	22.18	0.76
T_2: Black polyethylene mulch (Punched) - 200µ	88.13	76.30	8.16	27.19	0.89

T_3: Black polyethylene mulch (Unpunched) - 200 µ	88.40	78.20	8.29	27.65	0.91
T_4: Bi-Colour polyethylene mulch - 200 µ	88.57	80.60	8.10	26.95	0.86
T_5: Paddy Straw mulch - 10cm thickness	93.07	88.10	8.99	29.96	0.94
T_6: Forest Litter (Pine Needles) - 10cm thickness	92.70	87.93	8.00	26.66	0.89
T_7: Chopped lawn grass - 5cm thickness	91.73	87.33	7.65	26.61	0.87
T_8: Oxyfluorfen @ 0.5 L ha^{-1} (Pre-emergence herbicide)	86.17	79.60	7.41	24.69	0.85
T_9: Glyphosate @ 2.0 L ha^{-1} (Post-emergence)	85.83	80.07	6.69	22.29	0.82
T_{10}: Glufosinate ammonium@0.84 Kg ha^{-1}(Post-emergence)	86.13	79.90	6.98	23.28	0.84
T_{11}: Oxyfluorfen @ 0.5 L ha^{-1} (Pre-emergence herbicide) followed by Glyphosate @ 2.0 L ha^{-1} (Post-emergence)	89.97	86.93	8.45	28.16	0.92
T_{12}: Oxyfluorfen @ 0.5 L ha^{-1} (Pre-emergence herbicide) followed by Glufosinate ammonium @ 0.84 Kg ha^{-1} (Post-emergence)	90.70	87.80	9.16	30.53	1.00
T_{13}: No Weeding (Control)	82.57	70.51	5.52	18.39	0.65
C.D.($p \leq 0.05$)	0.949	0.945	0.604	1.771	0.137

Conclusion

The use of the combination of pre and post emergent herbicide was significantly effective in controlling weeds. Minimum weed population was found under T_{12} (Oxyfluorfen followed by Glufosinate ammonium). Maximum incidence of weeds was recorded under unweeded control. Furthermore significant influence of different weed management strategies was observed on initial and final fruit set in high density apple trees. Maximum final fruit retention was obtained under paddy straw mulch. The highest fruit yield per tree was recorded under T_{12} (Oxyfluorfen followed by Glufosinate ammonium) which was statistically at par with T_5 (paddy straw mulch). Minimum final fruit retention, fruit yield and yield efficiency was recorded under control indicating that weed management strategies are very much essential under high density orchard system for obtaining higher yield.

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