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Effective weed control strategy in tomato kitchen gardens – herbicides, mulching or manual weeding

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Effect of weed control on tomato (*Solanum lycopersicum* L.) crop has been rarely explored in kitchen gardens for improving fruit yield and quality. Therefore, we studied the impact of manual weeding, herbicide application and mulching (using polyethylene sheet) on tomato crop improvement in kitchen gardens. The data show significant differences among different treatments in terms of weed density/m^2, weed fresh biomass and dry biomass and quality of tomato plants in terms of plant height, fruit-bearing (fruits/plant) and yield (tonne/ha). Highest weed density/m^2 (3.5 ± 0.84) was observed in plots with herbicide treatment and it was similar to that in control. Weed fresh biomass was significantly reduced in all treatments. Manual weeding resulted in the highest number of fruits/plant (33.75 ± 1.67), plant height (60 ± 1.01 cm) and yield of tomato (4.45 ± 0.18 tonne/ha). Therefore, manual control proved to be the most effective treatment in terms of weed suppression and yield enhancement of tomato crop. It was also observed that in crop production mulching must be encouraged in the future weed management strategies.

Keywords: Herbicide, kitchen gardens, tomato, mulching, weed control.

TOMATO (*Solanum lycopersicum* L., Solanaceae) is a popular and nutritive vegetable crop ranking next to potato in the world's vegetable production[1]. It is an important source of minerals and antioxidants, including carotenoids, lycopene, vitamins C and E, and phenolic compounds, which play a key role in human nutrition in preventing certain cancers and cardiovascular diseases[2]. Being one of the most favourite vegetables, tomato is consumed in many ways[3].

Several factors are responsible for low yields of tomato. Among them, weed infestation in cultivated fields is the major factor which also reduces quality and value of the crop by competing for light, space and nutrients. Thus the farmer ends up spending more on agronomic practices[4]. On the other hand, weeds provide a safe harbour to many insect pests of tomatoes.

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In tomato production, although weed control has always been a vital constituent, its significance has increased since the introduction of sweet potato whitefly and development of the associated irregular ripening problems. Good weed control has been reinforced due to the increased incidences of various viral disorders of tomato plants. Weed control during the first four weeks is critical in many vegetable crops[5]. Marana *et al.*[6] estimated the critical period of weed competition to be 30–40 days after sowing, when the presence of weeds reduced fruit yield by 70% depending on stage and duration of competition[7]. These yield losses, in severe weed infestation, may rise up to 95% in tomato yield if no control strategy is employed[8].

Feeding the growing world population in terms of food production and security is one of the biggest challenges of the current era[9]. Increased prices of agricultural produce and inflation are limiting the availability of organic and healthy vegetables to most urban inhabitants[10]. Hence it is important to encourage urban communities to utilize the open spaces in their backyards to produce their own food[11,12]. With these objectives, the Centre for Agriculture and Bioscience International (CABi), Pakistan Chapter had initiated the Kitchen Gardening Training Programme for Women of Pakistan to produce kitchen crops for domestic use. As weed infestation in these small areas is the most common yield-limiting factor, this study was designed to evaluate weeding strategies to ensure clean and healthy vegetable production.

Several types of weed control practices are common in vegetable gardening, including manual hoeing, chemical control and mulching. Herbicides show excellent performance when soil moisture is high. Post emergence herbicides work best on plants that are not stressed for moisture. Non-stressed plants translocate the herbicide from where it is absorbed (mostly leaves) to the site of action[13,14]. Although herbicides can be effective in controlling weeds, they involve high cost, which is beyond the budget of small farmers in Pakistan. Moreover, chemical weed control also has its associated limitations at the time of application, including requirement of proper soil moisture, right stage of weed life cycle and soil compaction in field where power-driven rotary tillers are used for soil incorporation[15,16]. In addition, herbicide application requires particular equipment and expertise to ensure that proper rates are applied, and that human health and safety are not compromised.

Cultural practices such as hoeing and mulching are a well acknowledged and effective non-chemical weed control approaches. In mulching, soil surface is covered with different materials, including shredded plant materials, pebbles, plastic sheets and paper[17], which restrict weed germination by blocking sunlight and/or access to atmospheric oxygen for germination[18]. This practice may have additional benefits for farmers by conserving soil moisture. Whereas manual hoeing and picking of weed plants from crop can prove to be more efficient in small-scale gardening.

As limited recommendations are available for weed control on tomato production in kitchen gardens, this study was designed to develop an integrated weed control strategy using different weed control methods. The main objective was to evaluate the different weed control methods in terms of their effectiveness and efficiency.

To study the effect of different weed control methods on the yield of tomato crops in kitchen gardens, an experiment was conducted at the Kitchen Gardening Training Centre for Women, Faisalabad, Pakistan. In this study, manual weeding was compared with mulching (using black plastic sheets) and herbicide application.

Four of the common weed species, including foxtail (*Phalaris minor*), wild oats (*Avaena sativa*), goosefoot (*Chinopodium album*) and wild mustard (*Sinapis arvensis*) were selected for the study. To ensure uniform weed density across treatments, 10 seeds of each weed species were mixed and planted in each plot. Soon after germination, excess plants were thinned to keep uniform plant density of 4 plants/m^2. Two commercial varieties of tomato, viz. 'Naqeeb' and 'Riogrande' were selected for the study. Thirty days after sowing the seeds in the nursery, young seedlings were transplanted in raised seed beds at 30 cm distance, while the beds were 60 cm apart. Fertilizers were applied at recommended commercial rate and nitrogen was applied in two equal splits (first at the time of transplantation and second 30 days after transplantation). Synthetic herbicides – fenoxaprop-*p*-ethyl (Puma Super ® 750 EW Bayer Crop Science, Pakistan) and metribuzin (Sencor®70 WP, Bayer Crop Science, Pakistan) were applied at recommended rates using a flat fan nozzle sprayer for controlling both the grasses and the broad-leaved weeds respectively. In comparison, mulching was done by spreading black plastic sheets in furrows and bed. The seedlings were transplanted on raised beds through 2 cm holes cut in the sheets. Weed density/m^2, fresh and dry biomass of weed (kg/ha), tomato plant height (cm), number of fruits/plant and tomato yield (t/ha) were recorded as response indicators. Weed density was recorded 20 days after transplantation from the central three rows using visual counts/m^2 quadrant.

The experiment was laid out in a randomized complete block design with three replicates for each cultivar. As no significant differences were recorded between two cultivars ($F_{1,16} = 0.961$; $P = 0.342$), their data were pooled and reanalysed for presentation. Data collected were analysed using SPSS, first for normalization and assumption of homoscedasticity, and then ANOVA test was applied. On obtaining significant results, least significance difference test was used for comparison of means to identify the significant components of the treatment means[19]. The relationship between different factors was subjected to Pearson's correlation to generate a correlation matrix.

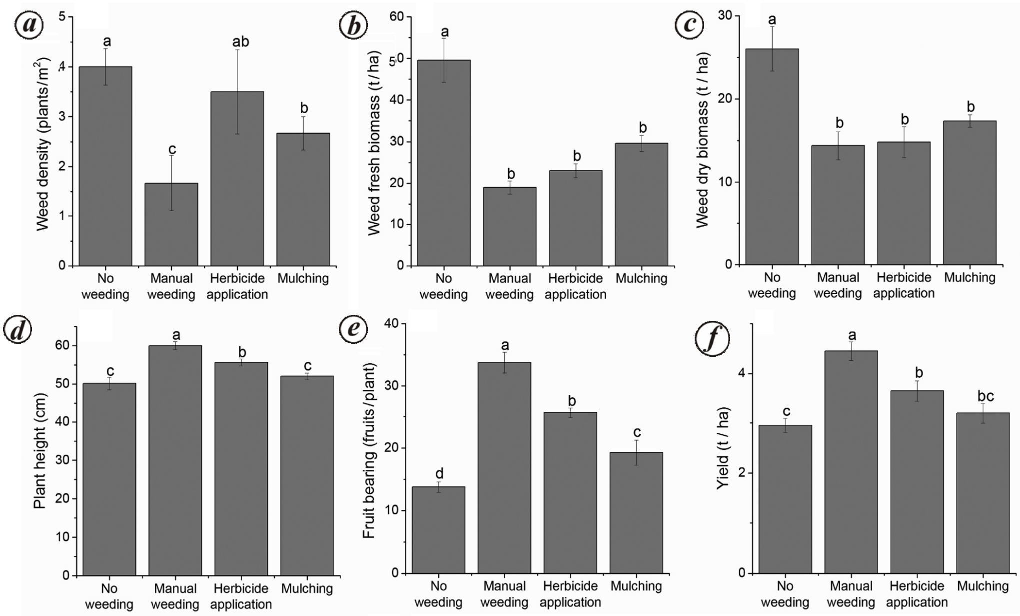

Figure 1. Effect of various weed control methods on (***a***) weed density; (***b***) weed fresh biomass; (***c***) weed dry biomass in tomato kitchen gardens, (***d***) plant height; (***e***) number of fruits/plant and (***f***) yield of tomato. Bars represent means and error bars are 95% CI. Bars sharing the same letters do not differ statistically from one another ($P > 0.05$; LSD test for multiple pairwise comparisons).

The data on weed density/m^2 showed that all the weed control methods had significantly reduced the weed cover compared to that in plots where no weeding was done ($F_{3,20} = 3.282$; $P = 0.042$; Figure 1 *a*). Highest weed control was observed in plots with manual weeding (Figure 1 *a*). However, it was not significantly different from the plots treated with herbicide. The plots where mulching was practised had significantly lower weed density than other treated plots (Figure 1 *a*). No significant correlation between weed density in each plot with weed biomass was observed ($r = 0.314$, $n = 24$, $P = 0.135$, two-tailed; Table 1 and Figure 2 *a*). However, the weed fresh and dry biomass were significantly different in each treatment plot compared to the control ($F_{3,20} = 20.147$; $P < 0.001$ and $F_{3,20} = 8.385$; $p < 0.01$ respectively). Weeds in control plots (with no weeding) accumulated significantly high biomass (both as fresh and dry) compared to all plots that were weeded (Figure 1 *b* and *c*).

To understand the effect of efficient weed control on tomato plant growth, data regarding tomato plant height were recorded and analysed. We noticed a significant but negative correlation between weed biomass and tomato plant height ($r = -0.653$, $n = 24$, $P = 0.001$, two-tailed; Table 1 and Figure 2 *b*). Tomato plants in all the plots with different weeding methods applied, were significantly taller compared to those in control plots ($F_{3,20} = 14.233$; $P < 0.01$). The tallest plants were in plots where manual weeding was done, followed by those with herbicide application (Figure 1 *d*). The plants in plots with mulching were significantly shorter compared to those in plots with other treatments and were statistically similar in height compared to those in control (Figure 2 *d*). Also, a strong and significant correlation between plant height and fruit-bearing (number of fruits/plants) was recorded ($r = 0.795$, $n = 24$, $P < 0.001$, two-tailed) (Table 1 and Figure 2 *c*).

Fruit bearing showed significant relation to various weed control methods applied ($F_{3,20} = 36.739$; $P < 0.01$). Significantly, the highest number of fruits/plant was produced when manual weeding was applied. This was followed by those in plots with herbicide application (Figure 1 *e*). In plots where mulching was practised, significantly less number of fruits/plant was produced compared to those in plots with herbicide treatment (Figure 1 *e*). In control plots, minimum number of fruits/plant was produced (Figure 1 *e*). Number of fruits/plants had a strong and significant positive correlation with total yield of tomato crops in kitchen gardens ($r = 0.813$, $n = 24$, $P < 0.001$, two-tailed) (Table 1 and Figure 2 *d*).

Crop yield observed in different treatments has clearly demonstrated a significant effect of weed control ($F_{3,20} = 12.755$; $P < 0.01$). Plots with manual weeding showed the highest yield, followed by those where herbicides were applied (Figure 1 *f*). Statistically similar yield was observed compared to that in control plots in plots where mulching was practised (Figure 1 *e*).

We have evaluated different weed control methods for weed management in tomato kitchen gardens. In general, all the treatments significantly controlled weeds in kitchen gardens, but the best practice, keeping in mind the small scale of kitchen gardens, was the manual weeding. The open soil surface and niches available to the weeds for free growth may result in excessive crop losses in the backyards; therefore effective weed management is

Table 1. Correlation matrix of relationship between different characteristics of weeds and production attributes of tomato in kitchen gardens

Characteristics	Weed fresh biomass	Weed dry biomass	Plant height	Fruits/plant	Yield/ha
Weed density	0.314	–0.02	–0.255	–0.482*	–0.609**
Weed fresh biomass		0.711**	–0.653**	–0.728**	–0.534**
Weed dry biomass			–0.537**	0.797**	0.612**
Plant height				–0.553**	–0.349
Fruits/plant					0.813**

*Correlation is significant at the 0.05 level (two-tailed). **Correlation is significant at the 0.01 level (two-tailed); $n = 24$.

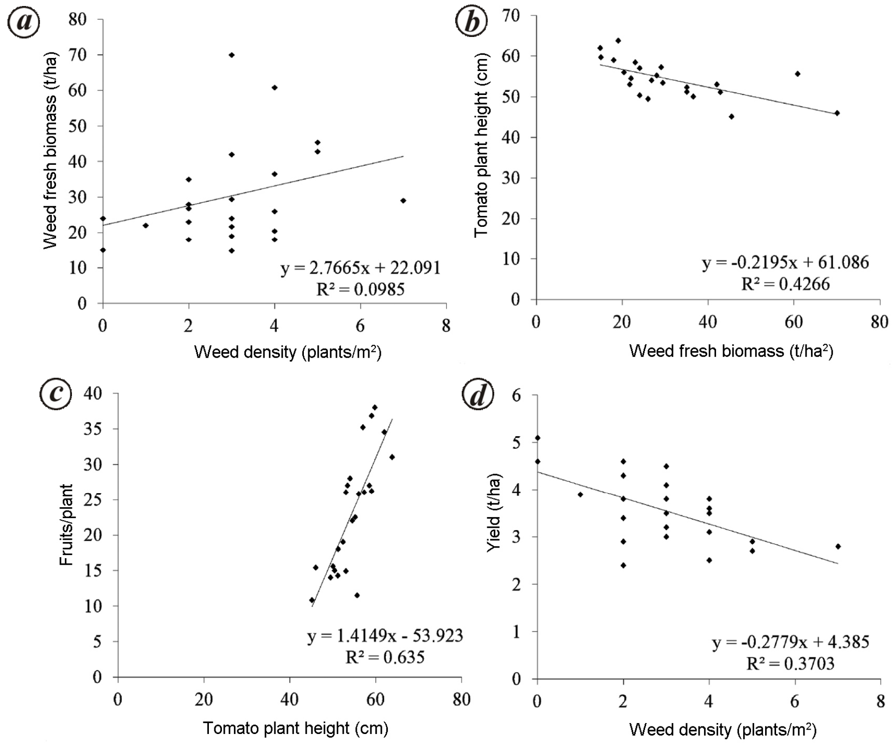

Figure 2. Interaction between (***a***) weed density and weed fresh biomass, (***b***) weed fresh biomass and tomato plant height, (***c***) tomato plant height and fruits per plant and (***d***) weed density and tomato yield in kitchen gardens. The regression coefficient values (r) are adjusted.

required, regardless of the scale of backyard farming. These results are in agreement with some earlier reports[20–22], wherein higher weed populations were reported in control plots compared to those where manual weeding was practised.

Timely eradication of weeds in plots with manual weeding could be the possible reason for lower weed fresh biomass in these plots. Similarly, the allelopathic effect of herbicides might have inhibited germination, which resulted in less fresh and dry biomass of weeds in plots with manual weeding and mulching. Manual weed control has been well documented as the most effective weed control method on small scale[23,24]. Unger and Ackermann[25] reported that cover crops (live mulches) reduced weed biomass from 41% to 94%. Results of this study are in agreement with earlier reports[26] suggesting that weed fresh biomass is significantly reduced in manual weeding due to the ensured removal of weeds at the early stage of crop establishment in the field.

The reduction in fruits/plant observed in control plots can be associated with increased competition for moisture, light and nutrients. In addition, the decrease in fruits/plant was proportional to the duration of weed competition. Higher number of fruits/plant in plots where weeding practices were applied compared to that in control plots, might be due to better growth and development of tomato plants and availability of more resources, which resulted in more fruit production. These results are in agreement with earlier findings[27]. The improved fruit bearing in tomato plants when proper weeding was applied ultimately resulted in higher yields, as is obvious in our results. Similar findings have been reported earlier by Hassan *et al.*[21], where increased plant height and improved yields were recorded due to application of proper weeding strategies.

Less competition for nutrients and other available resources in manual weed control plots resulted in higher yield of tomato in them. Our results are also confirmed by Chalfant *et al.*[28], who found that due to weed control, yield increase may be attributed to more favourable soil moisture and nutrient utilization. Siborlabane[29] also pointed out that the yield and quality of tomato for the market vary according to the type of mulch used in the plantation.

In conclusion, manual weed control has been the most efficient technique for enhancing all the growth and yield parameters of tomatos. The weed density/m^2, and fresh and dry weed biomass were drastically reduced compared to control plots. Plant height, number of fruits/plant and yield of tomato crop also increased when manual weeding was practiced compared to mulching or herbicide application.

Therefore, it is recommended that in kitchen gardens manual weed control should be performed at least twice in the full growing season of tomato. However, integrating mulching along with manual weeding can provide a synergistic effect in kitchen gardens.

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