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Weed Management in Mulberry (*Morus alba*): A Review

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ABSTRACT

Mulberry leaf is a sole food of silkworm *Bombyx mori* on which it feeds and produces silk called mulberry or mori silk. Due to its quality, mori silk has huge demand in national and international market and earns a valuable foreign exchange for the country. Weeds are of great menace as they interfere with production and quality of mulberry leaf and also add significant amount to the cost of cultivation. The factors which are congenial for heavy weed growth in mulberry are continuous mono-cropping, wider spacing coupled with regular application of manures and fertilizers after each crop harvest for maintenance of plantation. The reduction in production and quality of leaf has direct correlation with production of cocoons and quality silk. If losses due to weeds can be reduced by half from present level of 30-40%, leaf yield of mulberry will increase by 9-12 MT ha^{-1} $year^{-1}$ which can be utilized to produce 55-73.5 kg ha^{-1} $year^{-1}$ more raw silk to enhance the silk production of country. The effective weed control involves identification of weed flora, method of weed control and judicious combination of effective weed control methods. Depending upon soil type, agro climatic and ecological conditions, the nature and intensity of weed flora, their competitiveness varies. A total of 57-141 weed species belongs to 28-44 families have been reported in mulberry field across the country. Manual weeding in mulberry is an age old practice in India, but it is a tedious, expensive and time consuming. Black polyethylene mulching alone has been found economically advantageous over manual weeding in mulberry plantation. However no single method *viz.,* manual weeding, cover crop intercropping, herbicide and mulching found effective in weed control as compared to integrated method of weed control. Spraying of pre-emergence and early post emergence herbicides keeps the mulberry plantation in weed free conditions during the early stages. At later stage, when second flush of weeds attains peak after 30 days of pruning, spraying of herbicide is not possible due to chance of residual toxicity to the silkworm. Integration of pre herbicide followed by manual weeding at later stage or integration of hand weeding after pruning followed by either cover crop intercropping or mulching may helps to reduce damage due to weed, prevent silkworm from residual toxicity of herbicide and reduces manual weeding cost to some extent. Hence a brief review was presented to find out the influence of different weed management method in mulberry.

Key words: Economics, Leaf quality and yield, Mulberry, Weed management.

Mulberry (*Morus alba)* is the backbone of Indian silk industry as its leaf forms the basic food material for silkworm *Bombyx mori* which accounts 70% of the total raw silk produced in India (CSB Report, 2020). Globally, India ranks second in mulberry silk production next to China (CSB Report, 2019). In India, mulberry is cultivated for silkworm rearing over 2.38 lakh ha (CSB Report, 2020) across 26 states having major five growing states *viz.,* Karnataka (0.91 Lakh ha), Andhra Pradesh (0.33 Lakh ha), Tamil Nadu (0.18 Lakh ha), West Bengal (0.16 Lakh ha) and Jammu and Kashmir (0.08 Lakh ha) (CSB Report, 2019). Mulberry is planted in wider spacing and is resorted to five hectic prunings and crop schedule per year for its leaf for about 15-20 years. Continuous mono-cropping, wider spacing and regular application of manures and fertilizers under irrigated condition after each crop harvest for maintenance of plantation encourage heavy growth of weeds. They compete with mulberry for space, sunlight, soil moisture and nutrients, thus affect the leaf production (Shanmugam *et al*., 2012). Crop-weed competition severely reduces the growth and yield of mulberry (Shanmugam *et al*., 2012 and Sikdar *et al*., 1981). Besides yield losses, competition largely determines the quality of the produce as well. Bali and Pandit (2014) reported weeds in mulberry plantation deteriorate both leaf yield and quality. Further, quality of mulberry leaves fed to silkworm has direct link with the quantity and quality of cocoons (Muniyappa, 1990) as the silkworm derives 25% of silk protein from mulberry leaf on which it feeds (Bali and Pandit, 2014). Mulberry leaf qualities contribute in 38.2% success of cocoon crop (Matsumara *et al*., 1958). It is estimated that weeds can reduce mulberry leaf yield by 30-40% which otherwise would have been utilized for taking a rearing of 1500-2000 dfls ha^{-1} $year^{-1}$ to produce 110-147 kg of more raw silk. If this loss can be reduced by half, leaf yield of mulberry will increase by 9-12 MT ha^{-1} $year^{-1}$ which can be utilized to produce 55-73.5 kg ha^{-1} $year^{-1}$ more raw silk to enhance the silk production of country. In addition to

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incur potential yield losses, weeds also harbour insects and pathogens, which attack mulberry preventing plants to put forth normal growth. Therefore, weed management is very essential to economic mulberry cultivation. However, weed control in mulberry which are cultivated for silkworm rearing have many limitation like, increasing cost of cultivation, polluting the environment, chances of toxicity and residual effects on silkworm *etc.* Further the information regarding the weeds, their influence and management in mulberry is very scanty or not much consolidated. Therefore, effort have been taken for the first time to review different weed management studies carried out in mulberry to understand and identify the best sustainable weed management practices for improving the mulberry leaf yield and quality.

Weed flora of mulberry field

The first prerequisite for management of weeds is to identify the weeds and observe their appearance in the field. Depending upon soil type, agro climatic and ecological conditions, the nature and intensity of weed flora, their competitiveness varies (Bindroo *et al*., 2013). Several scientists studied the floristic composition of weed flora in mulberry garden at different locations and seasons across the country such as Bindroo *et al.* (2013) noticed 27 weed species in mulberry farm belonging to 15 family in southern Tamil Nadu with the dominant families were *poaceae* followed by *Amarantaceae* and *Asteraceae*; Das and Prasad (1972) reported the prevalence of 141 weed species belonging to 44 families in West Bengal. Vijaya and Razi (1975) observed 130 species belonging to 36 families in mulberry gardens in Mysore; Dhar *et al.* (1975) noted 57 weed species belonging to 28 families in Kashmir while Bhalerao *et al.* (2011) reported the occurrence of 58 weeds species belonging to 16 families in mulberry garden in three different seasons, namely rainy, winter and summer in Aurangabad with dominant families were *poaceae* followed by *fabaceae* and *asteraceae*. Bali and Pandit (2014) identified 123 species belonging to 35 families in mulberry garden of Jammu and Kashmir with *Asteraceae, Poaceae* and *Fabaceae* were the dominant families contributing collectively 45.52%. Banday *et al.* (2017) also reported a total of 98 species belonging to 38 families in mulberry garden at Kashmir with *Asteraceae* being the most dominant family followed by *Poaceae* and *Fabaceae.* Dangwal *et al.* (2010) also noticed that the families, *Asteraceae, Poaceae, Amaranthaceae* and *Fabaceae* constitute the major weed families throughout the world.

The most problematic weeds noticed under mulberry were *Digitaria marginata, Commelina benghalensis, Cynodon dactylon, Amaranthus viridis, Ageratum conyzoides* and *Cyperus rotundus* (Muniyappa and Shivakumar 1993). *Cynodon dactylon* and *Cyperus rotundus* were the dominants among the most troublesome perennial weeds infesting mulberry field and both of them together accounted for 79% of the total weed population (Kasiviswanathan *et al.,* 1978). Population of *Cynodon dactylon* alone was accounted for 38.89% in mulberry plantation (Shanmugam *et al.,* 2012).

Critical period of crop weed competition

Though weeds are competing with the plants for space, sunlight, soil moisture and nutrients, the extent of reduction in the growth and yield of mulberry is mainly depends on the time of occurrence in the field. The short time span in the life cycle of a crop, when weed causes maximum reduction in its yield called critical period of weed competition. Weeds present before the beginning or after the end of critical period certainly reduce crop yield but not that significantly. Therefore, the time of weeding is as important as the weeding itself. In mulberry initial period of 30-45 days after planting is considered as critical period for crop weed competition (Shanmugam *et al*., 2012 and Setua, 2009). Mulberry needs weed-free conditions for the first 30-45 days after planting to achieve satisfactory yield levels. (Krishna *et al.,* 2013a).

Losses caused by weeds

The yield loss in mulberry due to weed competition mainly depends upon the nature, intensity and duration of weed infestation. Crop-weed competition is a limiting factor in the growth of mulberry plant and unchecked weed population during the period leads to huge leaf yield loss ranging from 31.6-40% (Shanmugam *et al*., 2012 and Muniyappa, 1990). Weeds reduce the growth, yield and quality of mulberry leaf by competing for the soil nutrients for uptake (Jaiswal *et al.,* 2006; Muniyppa *et al*., 2000 and Muniyppa and Shivakumar, 1999). A study on weed competition done at CSRandTI, Mysore by Mishra *et al*. (1992) revealed that maximum quantity of weed biomass was produced in weedy check plots (8,369 kg ha^{-1}) which depleted 5,472 liters of water, 39.50 kg N, 27.00 kg P and 71.79 kg K ha^{-1} $crop^{-1}$. The uptake of nutrients and water increased with increase in competition duration being least in plots with competition for one week (3094 liters water, 19.51 kg N, 9.80 kg P and 42.79 kg K ha^{-1} $crop^{-1}$). Shivakumar *et al.* (1994) reported that under un-weeded condition mulberry could utilize only 29.82 kg ha^{-1} N, 2.97 kg ha^{-1} P and 19.1, kg ha^{-1} K, whereas weeds removed 30.85 kg ha^{-1} N, 11.64 kg ha^{-1} P and 57.4 kg ha^{-1} K. Muniyappa (1990) also conducted crop- weed competition study in mulberry and revealed that weeds removes 41.63 kg N, 13.01 kg P and 72.93 kg K ha^{-1} in un-weeded control, whereas the mulberry could utilizes only 13.51 kg N 2.06 kg P and 17.09 kg K ha^{-1}.

Certain weeds act as alternate and collateral host places and play some role in perpetuation of some of the pathogens. At CSR and TI, Mysore. Rao and Kumar (1985) reported that in addition to competition for food with mulberry, 13 weeds out of 45 screened *viz., Mimosa pudica*, *Parthenium hysterophorus*, *Oxalis corniculata, Cleoma viscosa, Borreria ocymoidas, Digera arvensis, Trianthema monogyna, Astereantha longifolia, Waltheria indica, Lagasca mollis* and *Brachiaria reptons* act as an alternate host of root knot nematodes showing severe infestation. In mulberry garden, weeds reduce the leaf yield by 50% and also act as an alternative host for many pests and disease pathogens

harmful for mulberry (Reddy *et al.,* 2000). Thus automatically affects the production of cocoon and silk (Setua *et al.,* 2008 and Isaiarasu 2005) as 38.2% success of cocoon crop depends on mulberry leaf quality (Matsumara *et al*. 1958).

Method of weed control

Though there are few methods of weed control practiced in mulberry cultivated for silkworm rearing, many of them have a limitation in adoption due to one or the other drawbacks like, increasing cost of cultivation, polluting the environment, chances of toxicity and the residual effects on silkworm *etc.* Hence, different weed control studies carried out in mulberry have been reviewed intensively for identifying economically sound and environmentally safe method of weed control.

Manual weeding

It is the age-old practice of weed control in mulberry. Many researchers have reported the benefits of manual weeding in enhancing weed control efficiency (WCE) in various crops. In mulberry, Shanmugam *et al.* (2009) reported that treatment comprising two manual weeding one at immediately after pruning and another at 25 days after pruning (DAP) had highest WCE (60%) compared to the treatment comprising of glyphosate plus mulching (55.8%) and glyphosate (53.55%). Setua *et al.* (2009) are of the opinion that manual weeding once on 25 DAP or twice on 25 DAP and 50 DAP registered least weed population, dry weight of weed biomass and enhanced the growth, leaf yield and to some extent qualities of mulberry leaves compared to un-weeded treatment. Sikdar *et al.* (1987) also proved that the manual weeding in mulberry gave significantly longer shoots, more number of branches per plant and more number of leaves per plant than control.

Cover cropping

Under irrigated condition mulberry is grown under paired row planting with wider spacing [(90+150)× 60 cm] coupled with heavy fertilization especially nitrogen (350 kg N ha^{-1} yr^{-1}) which lead to heavy growth of weeds between the mulberry plants. Although herbicides are effective in controlling weeds in mulberry at the initial growth stage, it is not possible to spray after 30 days growth of mulberry when the growth of weeds attains peak due to chance of residual toxicity to the silkworm (Setua *et al.,* 2009). Growing of cover crop as intercrop between the paired rows of mulberry plants occupies the space and utilizes the resources that would be otherwise available to weeds and suppresses the weeds mainly through the mechanism of allelopathy, competition and exerting physical effect on weeds by production of huge quantity of biomass. Vishaka *et al.* (2017) reported intercropping in mulberry helps in utilization of space between the mulberry plants, in turn it reduces the weed population, maintain soil health and improve utilization of water. However, ability of cover crop to suppress the weeds also differs depending upon its nature. Setua *et al.* (2008) reported that the minimum weed population was observed in mulberry intercropped with cowpea due to more shading effect, broad and thick leaf canopy while it was marginally higher with rice bean due to less shading effect and slightly narrow and thin leaf canopy and significantly higher in *Mimosa invisa* due to lack of shading effect by smaller size of bipinnately leaf canopy. Setua *et al.* (2009) proved that growing of cowpea intercrop in mulberry reduced weed population and dry weight by 32.9% and 38.8% respectively over weedy check without affecting the yield and quality of mulberry leaf. Shanmugam *et al.* (2012) are of opinion that manual weeding after pruning followed by intercropping with cowpea had 14.6% and 33.4% lower weed density and dry weight respectively with 47% more leaf yield than weedy check. Beside weed control cover crop can also benefits by additional income, controlling soil born disease *etc*. The cover crops are widely used in various cropping systems in agricultural system to control weeds but scanty information is available for weed control in mulberry (Setua *et al.,* 2009).

Chemical weed control

Spraying of 0.71% glycel (Glyphosate 41% SL) after 4 days of pruning of mulberry and pre emergence spray of diuron 1.0 kg ha^{-1} and pendimethalin 2.0 kg ha^{-1} in nursery could control the weeds to some extent (Muniyappa and Shivkumar 1993; Chandrasekharan and Venkatkrishnan 1991). Reddy *et al.* (2000) and Mishra *et al.* (1992) also had an opinion that 0.71% glycel application after 4 days of pruning followed by one manual weeding resulted in 58% reduction in weed dry weight while 5.18-15% improvement in mulberry leaf yields with additional saving of 250 mandays required for manual weeding. Application of Metolachlor 1.0 kg ha^{-1} as pre emergence in combination with glyphosate at 1.5 kg ha^{-1} as early post emergence gave better control of weeds with mulberry leaf yield advantages of 266.8% over weedy check (Babu and Muniyappa, 2001). Muniyappa and Shivakumar (1993) proved that application of diuron 1.25 kg ha^{-1}as pre emergence increased mulberry leaf yields from untreated control values of 768.39 kg ha^{-1} to 7871.92 kg ha^{-1}. Chandrasekharan and Venkatakrishnan (1991) reported that pre emergence application of diuron at 1.0 kg ha^{-1} and pendimethalin at 2.0 kg ha^{-1} in mulberry field significantly reduced the weed dry weight by 70% and 60% respectively over weedy check. Sikdar *et al.* (1987) noted that MSMA 2 litre + paraquat 1.5 kg a.i. ha^{-1} significantly reduced the weed dry weight by 71.6% with mulberry leaf yield advantages of 35.5% over weedy check. Application of Tafapon at 6.0 kg ha^{-1} as pre emergence reduced 28.9% weed dry weight in mulberry field compared to weedy check (Das and Prasad, 1972). Shanmugam *et al.* (2012) reported that early post emergence application of glyphosate at 10 ml + 20 ml ammonium sulphate + 2 ml soap solution per litre reduced the weed dry weight by 60.2% and improved the mulberry leaf yield by 16.8%. Some of the herbicides are selective in their efficacy towards control of specific weeds while some herbicides found phytotoxic to plants. Das and Prasad (1972) observed that simazine is more efficient than dalapon in

controlling *Eleusine indica* while dalapon is more effective in controlling the *Cyperus rotundus* than simazine. Kasiviswanathan *et al.* (1978) also reported that application of diuron, atrazine and simazine controlled weed population to an extent of 63.1, 62.8 and 55.1% over weedy check however, atrazine and simazine shown phyto-toxic effect on mulberry plant. Visible phytotoxic symptoms such as necrosis, leaf drop at 30 days after planting in alachlor treated plots at both doses of 3.0 and 6.0 kg ha^{-1} as pre emergence have been also reported by (Chandrasekharan and Venkatakrishnan, 1991). Effective weed management through diuron at 1.25 kg ha^{-1} as pre emergence resulted in an uptake of 74.47, 12.02 and 84.79 kg ha^{-1} N, P and K respectively by the mulberry crop and allowed only 1.43, 0.3 and 4.58 kg ha^{-1} N, P and K by weeds (Shivakumar *et al.,* 1994).

Mulching

Use of mulches to suppress the weeds is one of the mechanisms to enhance growth and yield of a crop (Mohler and Calloway, 1992). Poor growth and yield of mulberry in non mulched plot due to profused weed growth, which compete with mulberry crop for water and nutrients (Sahida *et al.,* 2019). Mulches can suppress the weeds either through exerting physical effect or producing allelochemicals. Of these two strategies, retention of allelopathic crop residues as mulch or incorporation into field found to be the most effective. Based on the materials used, the mulches may be categorised into organic mulch, dust mulch, synthetic or chemical mulch, gravel or sand mulch etc. Although mulching has been shown to be beneficial in controlling weeds, the level of weed control depends on the type of material used. Gangawar *et al.* (2000) who reported that paddy straw mulching in mulberry field showed maximum mulberry leaf yield (46%) compared to Sorghum (32.4%) and blackgram mulch (23.08%) over control. Shanmugam *et al.* (2012) revealed that once manual weeding followed by mulching with coir pith significantly reduced the dry matter production of total weeds compared to twice manual weeding. Shivakumar *et al.* (2001) reported that the ragi straw incorporation or burnt at 10 t ha^{-1} improved the efficiency of weed control treatments with 18% additional benefits in mulberry leaf yields. Purohit *et al*. (1990) have reported 24.16-48.63% increase in leaf yield in mulberry by the use of mulches. Besides improvement in the growth, yield and weed control in mulberry certain mulches positively influence the soil temperature, moisture and nutrient uptake. Mir *et al.* (2015) inferred that mulberry twigs, dried weeds and paddy grass mulch not only improves weed control efficiency (54%, 62% and 55% respectively) and yield of mulberry (12%, 10% and 11% respectively) in rainfed conditions but also improves soil (2-3%) and leaf moisture (1, 2, 3% respectively). Das *et al.* (1990) who reported that, green manuring with cowpea, horsegram and dry weed mulches increased the total nitrogen in mulberry leaf by 17.9, 22.2 and 9.8%, respectively over no mulch. Sakthivel (2019) reported black polythene mulching registered significantly higher values of 97.06% and 93.42% of weed control efficiency, 60.20% and 52.52% increase in soil moisture content and 58.14 and 25.89 % increase in mulberry leaf yield over weedy check and manually weeded plot respectively. Purohit *et al*. (1990) observed that black polythene mulch improved the leaf yield by 48.1% over control.

Economics of weed management

Manual weeding though it is effective but scarce labour and hike in labour wages makes it economically not viable for weed control in mulberry where it requires 457-500 mandays ha^{-1} $year^{-1}$ (Manjunatha *et al.,* 2020; Krishna *et al.,* 2013 and Dandin and Giridhar*,* 2000). Krishna *et al.* (2013) also inferred that repeated manual weeding at 20, 40 and 60 days after pruning in mulberry found expensive than herbicidal treatments. Mishra *et al*. (1992) noticed that combination of 0.71% glycel application after 4 days of pruning followed by one manual weeding can save 50% mandays (250 mandays) required for manual weeding. Daramola *et al.* (2020) also observed that application of butachlor plus manual weeding in cotton had the highest net returns and cost benefit ratio and resulted in 37-80% higher net return and 16-139% higher benefit cost ratio than two manual weedings, the weed-free check and/or application of either herbicide alone. Setua *et al.* (2009) reported growing of cowpea in between mulberry plants resulting in 41% reduction in the cost of digging-cum-weeding activity. Intercropping of sorghum with cowpea and green gram smothered weeds and reduced manual weeding cost (Rao and Shetty, 1981). Intercropping of baby corn with mulberry exhibit the benefit of control of weeds, fetching an additional income of ` 16872/- over control without hampering the main crop (Shivaprakash *et al.,* 2008). Sakthivel *et al.* (2011) reported that mulberry plot mulched with black polyethylene increased net returns by ` 8950/- over manually weeded plot.

CONCLUSION

From this review it can be concluded that, successful weed control is required in mulberry cultivation for production of both good quality and quantity of mulberry leaf. Weed control methods practiced in mulberry have many limitation in adoption like, increasing cost of cultivation, polluting the environment, chances of toxicity and residual effects on silkworm *etc*. Pre or early post emergence herbicide application and manual weeding immediately after pruning has the initial advantage to mulberry over the weeds but not successful in season long control of weeds. Manual weeding adds significant amount to the cost of cultivation and spraying of herbicide on second flush of weeds at later stages is not possible due to chances of toxicity to silkworm. Therefore, minimizing manual weeding cost to some extent by integration of pre herbicide followed by manual weeding at later stage or integration of manual weeding after pruning followed by either cover crop intercropping or mulching may helps to reduce damage due to weeds and prevent silkworm from residual toxicity of herbicide.

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