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Evaluation of weed management options for cotton (*Gossypium hirsutum*) cultivation at hill base in Bandarban

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ABSTRACT

An experiment was conducted in the experimental field of Hill Cotton Research Station, Bandarban hill district in 2017 to see the effect of weed control methods on weed infestation behavior and performance of cotton. The treatments were non-selective herbicide + hand weeding, non-selective herbicide + hand weeding+ earthing-up, post-emergence herbicide, post-emergence herbicide + hand weeding, hand weeding, hand weeding + earthing-up, and control, arranged in RCB design. Thirty six weed species were found to infest the experimental field of which 10 were grasses, 6 were sedges, and 20 were broadleaves. Application of post-emergence herbicide with three hand weeding provided the highest weed control efficiency (74.55%) compared to other treatments in cotton field. Pre-planting application of non-selective herbicide followed by hand weeding and earthing-up contributed to the tallest cotton plants (160.80cm) at harvest and the highest number of cotton flower buds (12/plant) at 60 days after sowing, whereas leaf development at 60 DAS was favorably affected by the application of three hand weeding + earthing-up (71.33 leaves/plant). Application of three hand weeding accompanied by earthing-up contributed to the highest cotton fiber yield (3.889 t ha^{-1}). In the context of productivity of cotton, application of three hand weeding along with earthing-up seemed to be the best option for weed management in cotton at hill base as observed through this study.

Introduction

Cotton cultivation as monocrop has been gaining momentum in the Chittagong Hill Tracts (CHTs) in recent years as the Cotton Development Board aims to gradually replace tobacco cultivation with high yielding varieties of cotton in the CHT. Around 12000 farmers cultivate 14,280 ha of hilly lands with cotton in the CHT (Ahmed and Stacey, 2016). In 2014-2015, 5810 bales of cotton were produced in CHT region (Ahmed and Stacey, 2016). The Cotton Development Board (CDB) has undertaken a program to increase gradually domestic cotton production to 670,000 bales (from 100,000 hectares) by the end of 2021.

Weeds can directly hinder cotton growth by competing for available resources and, in some cases, by releasing allelopathic chemicals. However, the degree of damage from weed competition is related to the weed species, weed densities, and the duration of weed-cotton competition as related to the life cycle of the cotton plants (Jamshid *et al*., 2015). Weed competition at square formation and flower formation stages proved to be more harmful as compared to the competition at later stages (Farrell *et al*., 2001). Weed management takes into account all relevant control tactics and methods available locally, evaluating their potential cost effectiveness. It does not, however, consist of any absolute or rigid criteria. Engaging with farmers involves implementing practices that are perceived as practical and valuable to their operations (Dumka *et al*., 2004).

In Bangladesh as well as in the CHT farmers traditionally practice hand weeding which involves 4-5 times of weeding operation for a cotton crop. The practice, however, is very laborious, time consuming and costly. In recent years herbicide application has been gaining momentum as a cheap and effective alternative to manual weeding in the CHT. Using herbicides simply replaces labor. Ever since, the main limiting factor for the size of *Jhum* fields has been the labour requirement for weeding (Khisa and Mohiuddin, 2015).

As a cash crop, cotton demands priority for controlling weed and other pests, so that we can

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increase the fiber production to improve the livelihood of farmers. Therefore, it is essential to develop appropriate weed management options for successful cotton production and at the same time preserving the precious environment. Therefore, the present study was undertaken to determine the effect of selected weed control treatments on weed infestation behavior, growth and development of cotton plants and to evaluate the yield performance of cotton in cotton field.

Materials and Methods

The experiment was conducted during in the experimental field of Hill Cotton Research Center, Bandarban Hill District July, 2017 to January, 2018. The location of the plain land experimental site was situated at 22.13^{o} N latitude and 92.13^{o} E longitude with an elevation of 36 meters above the mean sea level.

Soil and climate

The soil of the experimental site belongs to the Northern and Eastern Hills Agro-ecological Zone (AEZ 29) with soils being yellow brown to strong brown, permeable, friable loamy, and low in moisture holding capacity. The soil was strongly acidic having a pH of 5.0-5.5. The experimental site is situated in a sub-tropical climatic zone, characterized by heavy rainfall during the months from May to September and scanty rainfall during the rest of the year.

Plant materials

The crop tested in this experiment was American cotton (*Gossypium hirsutum*). Cotton seeds were collected from the Hill Cotton Research Center, Bandarban.

Experimental design

The experiment was laid out Randomized Complete Block Design with 3 replications having unit plot size 20 m^2. Distance from plot to plot was 0.5 meter and block to block was 0.5 meter.

Treatments

There were 7 treatments. The treatments were T_1: non-selective herbicide + hand weeding, T_2: non-selective herbicide + hand weeding+ earthing-up, T_3: post-emergence herbicide, T_4: post-emergence herbicide + hand weeding, T_5: hand weeding, T_6: hand weeding + earthing-up, and T_7: control.

Land Preparation

The land was prepared by cleaning and ploughing. Standing vegetation on the field was slashed on 01 July, 2017 and cleaned. Then the land was ploughed with hand-plough to make the soil friable and to allow regrowth of weeds. Glyphosate was then applied @ 3.00 L/ha in the designated treatment plots on 10 July, 2017.

Sowing of seeds

Seeds were sown on July 18, 2017. All the seeds were soaked in water for 24 hours. On the following day seeds were mixed with soil and were sown in small pits in soil. Three seeds were put in each pit and then covered with soil. Seeds were sown in lines keeping 80 cm space between lines and 30cm between pits.

Herbicides application

Pre-planting herbicide Glyphosate @ 3.0 L/ha was applied in the treatment plots at 7 days before sowing. Pre-emergence herbicide Pendimethalin @ 3.00 L/ha was applied in the designated treatment plots 5 days after sowing. Post-emergence herbicide Pyrazosulfuron ethyl @ 2.0 L/ha was applied in the designated treatment plots 14 days after sowing in the treatment plots. Herbicide was mixed well by agitating and then the herbicide mixture was sprayed @ one liter per plot.

Hand weeding and earthing up

Three hand weeding were done at 20, 40, and 60 days after sowing (DAS). Earthing up was done at 60 DAS.

Intercultural operations

Intercultural operations such as thinning, replanting, gap filling, insecticide spray and other necessary cultural operations were done when required.

Collection of data

Weed parameters

Weed diversity and abundance

The data on weed diversity were recorded at 30, 60, 90, and 120 days after sowing (DAS). Visual abundance was calculated through visual observation on the size of infestation of weeds. Accordingly weeds were grouped into four categories i.e. 4= High abundance; 3= Medium abundance; 2= Low abundance; 1= Very low abundance.

Weed biomass

The data on weed biomass were recorded at 30, 60, 90, and 120 days after sowing (DAS) by using plant quadrat of 0.25m^2.

Weed control efficiency

Weed control efficiency was calculated with the following formula:

$$Weed\ control\ efficiency\ (WCF) = \frac{DMC - DMT}{DMC} X100$$

Where,
DMC = Weed dry matter production in unweeded treatment
DMT = Weed dry matter production in weed control treatment

Crop growth parameters

Plants were sampled at 30 days interval starting from 30 DAS till maturity. At each sampling data were recorded on plant height (cm), number of leaves plant^{-1} and number of flower buds plant^{-1}.

Plant height was measured from the base of plant up to the tip of the flag leaf. Plant height was taken in meters of five plants randomly chosen from each plot. The number of leaves was counted from five plants randomly chosen from each plot. The number of flowers was counted from five plants randomly chosen from each plot.

Yield and yield components

Cotton bolls per plant: At maturity 5 cotton plants were harvested from each treatment plot. All the cotton bolls from the sample plants were counted. Then effective and non-effective cotton bolls/plant was calculated separately.

Weight of individual cotton bolls (g): At maturity 10 matured cotton bolls were collected from each treatment plot. Then average weight of individual cotton boll was measured in grams.
Estimated fiber yield: It was calculated by using the following formula.
Cotton yield (t/ha) = Effective cotton bolls/plant X individual boll weight X cotton plant population per hectare.
Actual fiber yield: Actual fiber yield was calculated by multiplying the total cotton weight per treatment plot with 500 to estimate the cotton yield per hectare of each treatment.
Plant dry weight: After harvesting the cotton bolls, five plants from each plot were taken by cutting the plants from base (above ground portion). The collected plants were then sun dried for 72 hours. The plant samples were then oven dried at 50^{o}C for 72 hours. Then weight of dried plant samples was measured.

Data analysis

All the data were compiled in Microsoft Excel and analyzed using the software Statistix 10. The data were analyzed to calculate ANOVA and LSD.

Results and Discussion

Weed diversity in cotton field in plain land

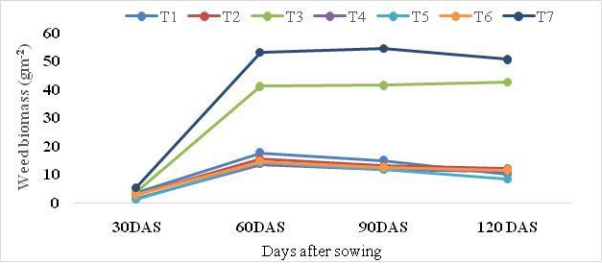
A total of 36 weeds species were found to infest the experimental field on the plain land. Among them 10 were grasses, 6 were sedges, and the rest 20 were under broadleaf category. Table 1 shows the Weed species found in the experimental plots in the field.

Weed biomass

Weed biomass increased in all the treatments up to 60 DAS, and thereafter declined slightly until end of the season (Figure 1). At 60 DAS, the highest weed biomass (53.13 g m^{-2}) was recorded in Control treatment. Among the weed control treatments, T_4 treatment (post-emergence herbicide + hand weeding) contributed to the lowest weed biomass (13.52 g m^{-2}), whereas T_3 treatment (post-emergence herbicide) incurred the highest amount of weed biomass (40.99g m^{-2}). All other treatments contributed to weed biomass at lower ranges. Data thus indicated that, single weed control method was not sufficient to combat weed problems in cotton field effectively since higher weed biomass were noticed in this treatment (T_3).

Table 1: Weed diversity in cotton field in plain land

Common/local name	Scientific name	Species (No.)	Visual abundance*
Grass			
Large crabgrass (Anguli ghash)	*Digitaria sanguinalis* L.	1	4
Southern cutgrass (Arail)	*Leersia hexandra* Sw.	1	4
Goose grass (Chapra)	*Eleusine indica* L.	1	4
Crow foot (Kakpaya)	*Dactyloctenium aegyptium* L.	1	3
Bermuda grass (Durba)	*Cynodon dactylon* L.	1	3
Knot grass (Angta)	*Paspalum distichum* L.	1	3
Saramolla grass (Mona)	*Ischaemum rugosum* L.	1	2
Chinese sprangle top (Fulka ghash)	*Leptochloa chinensis* L.	1	2
Torpedo grass	*Panicum repens* L.	1	1
Chinese lovegrass (Premkanta)	*Chrysopogon aciculatus* L.	1	1
Unknown grasses		0	
Grass Total		10	
Sedge			
Spike Sedge	*Cyperusa kyllingia* L.	1	4
Flat Sedge	*Cyperus compressus* L.	1	4
Yellow nutsedge (Haldeymutha)	*Cyperus esculentus* L.	1	4
Fragrant flatsedge	*Cyperus odoratus* L.	1	3
Slender spike sedge (Fulcheich)	*Cyperus tenuispica* L.	1	2
Joina	*Fimbristylis miliacea* L.	1	1
Unknown sedges		0	
Sedge total		6	
Broadleaf			
Spiny amaranth	*Amaranthus spinosus* L.	1	4
Wild tobacco (Bon tamak)	*Nicotiana plumbaginifola* Viv.	1	4
Tulsi	*Ocimum tenuiflorum* L.	1	4
Lambs quarter (Bathua)	*Chenopodium album* L.	1	4
Croton	*Croton sparsiflorius* L.	1	4
Fern (Dheki Shak)	*Dryopteris fillixmas* L.	1	3
Broom weed	*Scoparia dulcis* L.	1	3
Clammy ground cherry (Foska Begun)	*Physalis heterophylla* L.	1	3
False daisy	*Eclipta alba* L.	1	3
Asthma plant	*Euphorbia hirta* L.	1	3
Hatishur	*Heliptropium indicum* L.	1	3
Shame plant (Lojjaboti)	*Mimosa pudica* L.	1	2
Purslane (Nunia)	*Portulaca oleracea* L.	1	2
Redroot pigweed	*Amaranthus retroflexus* L.	1	2
Electric daisy (Ting flowers)	*Acmella ciliate* Kunth.	1	2
Goat weed (Chagla gacha)	*Ageratum conyzoides* L.	1	2
Iron weed	*Vernonia patula* Merr.	1	1
Gripe weed	*Phyllanthus urinaria* L.	1	1
Fine leaf fumitory	*Fumaria parviflora* L.	1	1
Panighash	*Lindernia anagallis* Burm.f.	1	1
Unknown broadleaves		0	
Broadleaf total		20	
Total weed species		36	

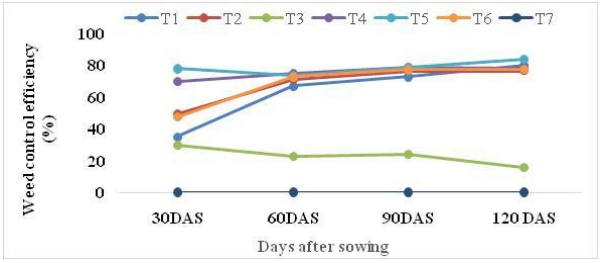


T_1= Pre-planting herbicide + Hand weeding; T_2= Pre-planting herbicide + Hand weeding + Earthing-up; T_3= Post-emergence herbicide; T_4= Post-emergence herbicide + Hand weeding; T_5= Hand weeding; T_6= Hand weeding + Earthing-up; T_7= Control

Figure 1: Weed biomass as affected by weed control treatment in plain land

Weed control efficiency (WCE)

Weed control efficiency had reciprocal relationship with weed biomass, i.e. the lower the weed biomass, the higher the WCE. WCE was lower at early crop growth stage i.e. 30 DAS, increased progressively until the end of the growing season (Figure 2). At 60 DAS the highest WCE (74.55%) was observed in T_4 treatment (post emergence herbicide + hand weeding), being followed by (73.61%) T_5 treatment (hand weeding) and (72.69%) T_6 treatment (hand weeding+earthing up). The lowest WCE (22.85%) was observed in T3 treatment (post-emergence herbicide). Data thus revealed that, single method for weed control could not suppress weeds effectively, rather combination of chemical and non-chemical methods seemed essential. Because, cotton is a long duration crop, and satisfactory WCE at early stages provided by any single weed control method at early stage could not be sustained during mid growth stages.



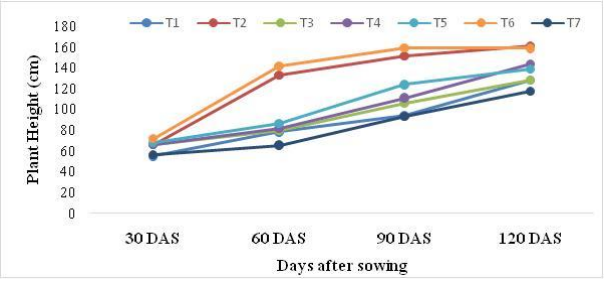
T_1= Pre-planting herbicide + Hand weeding; T_2= Pre-planting herbicide + Hand weeding + Earthing-up; T_3= Post-emergence herbicide; T_4= Post-emergence herbicide + Hand weeding; T_5= Hand weeding; T_6= Hand weeding + Earthing-up; T_7= Control

Figure 2: Weed control efficiency (%) as affected by weed control treatment in plain land

Performance of cotton as affected by weed control treatment

Plant height

Plant height increased progressively up to 120 DAS, and then reached a plateau (Figure 3). At 120 DAS, the tallest plants (160.80cm) were produced in the plots receiving Pre-planting herbicide followed by hand weeding and earthing-up (T_2), while the shortest (127.93cm) were recorded in the plots receiving post emergence herbicide (T_3). Results thus revealed that, T_2 treatment (Pre-planting herbicide + hand weeding + earthing-up) performed the best in terms of plant height on plain land.



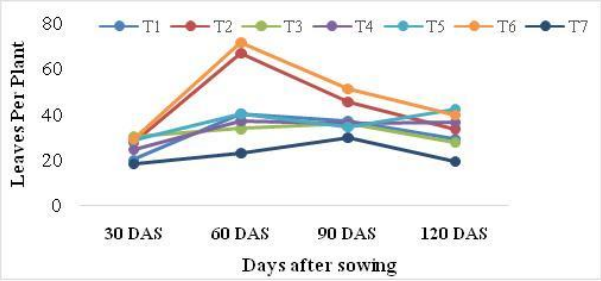
T_1= Pre-planting herbicide + Hand weeding; T_2= Pre-planting herbicide + Hand weeding + Earthing-up; T_3= Post-emergence herbicide; T_4= Post-emergence herbicide + Hand weeding; T_5= Hand weeding; T_6= Hand weeding + Earthing-up; T_7= Control

Figure 3: Cotton plant height as affected by weed control treatment in plain land

Leaf development in cotton

Cotton leaf development was low at early crop growth stage, which increased progressively up to 60 DAS, and then decline towards of the end of the season (Figure 4). At 60DAS, the highest number of cotton leaves/plant (71.33) were recorded in the plots receiving hand weeding + earthing up (T_6) and the trend continued throughout the season, and T_2 treatment receiving pre-planting herbicide + hand weeding + earthing up was in the second position. The lowest number of leaves/plant (22.67) were recorded in control plots (T_7) (Figure 4). Among the treatment plots, the lowest (33.33) number of plant leaves were recorded in the plots receiving only post-emergence herbicide (T_3). Data thus revealed that, since hand weeding coupled with earthing up might helped higher leaf development throughout the season, addition of

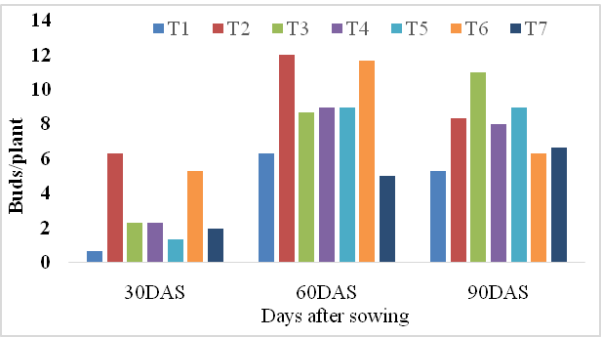
pre-planting herbicide was not essential in this regard (Figure 4).



T_1= Pre-planting herbicide + Hand weeding; T_2= Pre-planting herbicide + Hand weeding + Earthing-up; T_3= Post-emergence herbicide; T_4= Post-emergence herbicide + Hand weeding; T_5= Hand weeding; T_6= Hand weeding + Earthing-up; T_7= Control

Figure 4: Leaf development in cotton as affected by weed control treatment in plain land

Flower bud development



T_1= Pre-planting herbicide + Hand weeding; T_2= Pre-planting herbicide + Hand weeding + Earthing-up; T_3= Post-emergence herbicide; T_4= Post-emergence herbicide + Hand weeding; T_5= Hand weeding; T_6= Hand weeding + Earthing-up; T_7= Control

Figure 5: Flower bud development in cotton as affected by weed control treatment in plain land

Flower bud development was monitored at three Sampling dates, i.e. 30, 60, and 90 DAS. Number of flowers/plant reached its peak at around 60 DAS (Figure 5). At 60 DAS, the highest number of flower buds (12/plant) were produced in the plots receiving Pre-planting herbicide, being closely followed by hand weeding and earthing up (T_2) with 11.67 buds/plant, while the lowest (5/plant) were recorded in the control plots (T_7). Apart from control environment, the lowest number of flower buds (6.33/plant) was recorded in T_1 treatment (Pre-planting herbicide + hand weeding). At 90 DAS, however, T_3 treatment scored the highest number of flower buds/plant, being followed by T_5 and T_4 treatment (Figure 5).

Yield performance of cotton

Yield performance of cotton has been provided in Table 2. Actual yield based on crop cutting indicated that, the highest yield of 3.889 t/ha was contributed by T_6 treatment (hand weeding + earthing up), being followed by 3.435 t/ha in T_3 treatment (Pre-planting herbicide + hand weeding + earthing up). The highest fiber yield in T_6 treatment might be due to the highest number of cotton bolls/plant (16.33) and highest individual boll weight (6.03g). The lowest fiber yield (0.844 t/ha) was obtained in control treatment (T_7). Apart from control treatment T_3 treatment (post-emergence herbicide) contributed to the lowest fiber yield 2.062 t/ha (Table 2). Worst performance by this treatment (T_3) might be due to the lower number of bolls/plant (8.33) as well as lightest individual bolls (4.31g). Results revealed that the plots which received earthing-up treatment (T_2 and T_6) produced higher number of cotton bolls per plant and heavier bolls which might led to higher fiber yield.

Table 2: Yield performance of cotton as affected by weed control treatment in plain land

Treatment	Effective bolls/plant	Non-effective bolls/plant	Boll wt. (g)	Fiber yield (t/ha)	Stover yield (t/ha)	Harvest Index
T_1	7.67	0	4.87	2.357	1.787	0.57
T_2	11.33	1.33	5.93	3.435	2.098	0.62
T_3	8.33	0.33	4.31	2.062	1.221	0.63
T_4	11.00	0	4.65	2.444	2.353	0.51
T_5	11.00	0.67	4.71	2.295	2.028	0.53
T_6	16.33	0.33	6.03	3.889	3.127	0.55
T_7	4.67	0	4.12	0.844	1.546	0.35
CV	1.384	0.42	2.5587	0.0865	0.0275	
SE	23.86	189.98	8.96	28.62	26.17	

T_1= Pre-planting herbicide + Hand weeding; T_2= Pre-planting herbicide + Hand weeding + Earthing-up; T_3= Post-emergence herbicide; T_4= Post-emergence herbicide + Hand weeding; T_5= Hand weeding; T_6= Hand weeding + Earthing-up; T_7= Control

Results showed that, there existed positive relationship between weed infestation pattern hence weed control efficiency and yield components. Particularly weed control efficiency contributed much towards since relationship between WCE and bolls/plant (Figure 6) was more prominent compared to that with individual boll development (Figure 7). Again, it was also noticed that, weed infestation behavior at 60 DAS onwards played more important role than 30 DAS (Figure 6 & 7). Similar trend was also noticed in case of relationship between WCE and fiber yield (Figure 8). Results thus indicated that weed infestation during mid crop growth stages were more critical to yield formation in cotton. It became more evident in Figure 8, where it was clear that WCE at 60 DAS and onwards, particularly at 60 DAS had closer relationship with fiber yield than at 30 DAS. However, it was evident that in case of yield formation both number of bolls/plant and individual boll development played dominant role with emphasis on boll development (Figure 9).

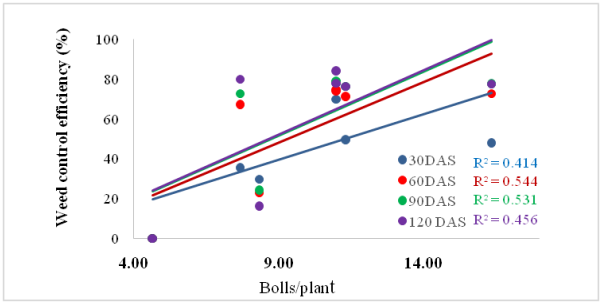


Figure 6: Relationship between weed control efficiency and number of cotton bolls/plant in plain land

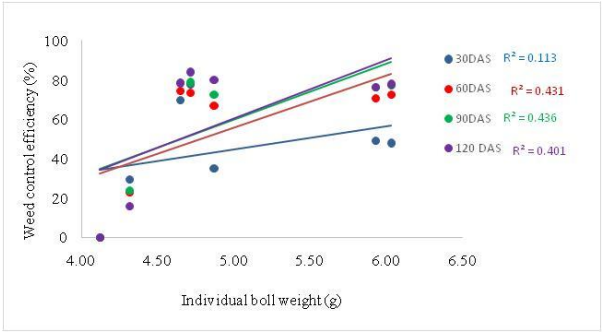


Figure 7: Relationship between weed control efficiency and individual boll weight in plain land

From results, it might reasonably be argued that, for cotton as a non-synchronous crop it is important to keep the field weed free during a longer period of time rather than early weed control measures. Yield data in Table 2 also revealed that single weed control measures could not perform well compared to multiple tactics covering wider periods of crop growth stages in cotton cultivation.

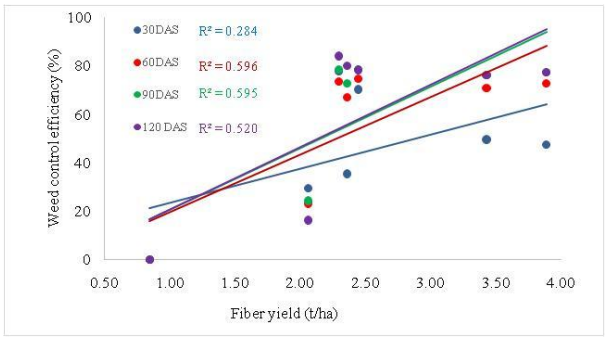


Figure 8: Relationship between weed control efficiency and cotton fiber yield in plain land

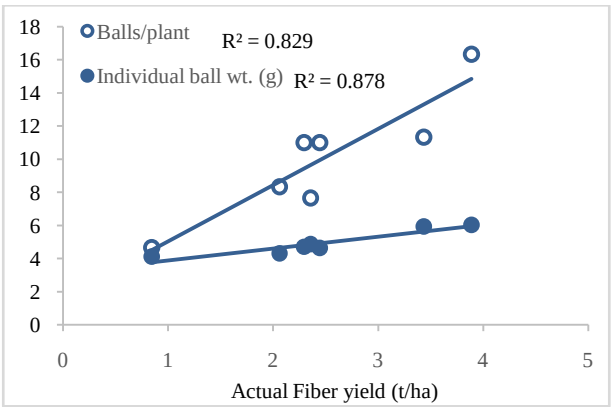


Figure 9: Relationship between cotton fiber yield and yield components of cotton in plain land

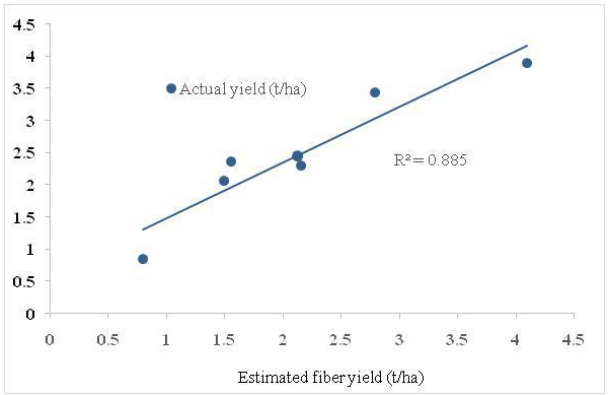


Figure 10: Relationship between estimated and actual fiber yield of cotton in plain land

Fiber yield was also estimated base on yield components and assuming 41625 cotton plants/ha at 80cm X 30cm planting configuration. The

highest estimated fiber yield was calculated as 4.10t/ha in T_6 treatment, while the lowest (0.80 t/ha) was observed in control treatment (T_7) (Table 3). Trends in estimated fiber yield were found at par with trends in actual yield having strong correlation (0.940903). A strong positive relationship (R^2= 0.8853) also existed between two sets of yield (Figure 10), thus reaffirming the soundness of the experimental procedure.

Table 3: Change in cotton fiber yield in plain land

Treatment	Estimated yield (t/ha)	Actual yield (t/ha)
T_1	1.555	2.357
T_2	2.798	3.435
T_3	1.496	2.062
T_4	2.127	2.444
T_5	2.157	2.295
T_6	4.100	3.889
T_7	0.800	0.844
Coefficient of correlation	***0.940903***	

T_1= Pre-planting herbicide + Hand weeding; T_2= Pre-planting herbicide + Hand weeding + Earthing-up; T_3= Post-emergence herbicide; T_4= Post-emergence herbicide + Hand weeding; T_5= Hand weeding; T_6= Hand weeding + Earthing-up; T_7= Control

Results of the experiment revealed that single method based weed management approach was not sufficient to combat complex weed problems in cotton cultivation in plain land hence hill valleys. Rather combination of approaches including earthing up might be the right option to combat weed problems and ensure higher fiber yield on plain land and/or plain lands.

Conclusions

Application of post-emergence herbicide along with three hand weeding provided better weed control efficiency compared to other weed management techniques on plain land. Application of three hand weeding along with earthing up provided higher fiber yield in cotton on plain land. Results further revealed that in plain land hand weeding followed by earthing up provided better weed control efficiency and superior yield.

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