Effect of Integrated Weed Management Practice on Weeds and Yield of Cotton

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Abstract

Weeds are one of the causes of underproduction which leads to severe losses in cotton yield due to competition and increased production costs. This study was aimed at determining the effect of different weed management practices on weeds and cotton yield in the Middle Awash, Ethiopia. The experiment was conducted during the 2017 and 2018 cropping seasons at Werer Agricultural Research Center and Gewane cotton commercial farm. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Treatments consisted of various combinations of mechanical, cultural, and chemical control methods. These were: hand weeding + inter-culturing, pre-irrigation + hand weeding, pendimethalin + hand weeding, pre-irrigation + inter-culturing, pendimethalin + inter-culturing, pre-irrigation + pendimethalin, pre-irrigation, and control. Data on weed density and cotton yield and yield components were recorded. Weed density, cotton boll number per plant, boll weight, and seed cotton yield were significantly affected by weed management practices. Hand weeding + inter-culturing and pendimethalin + inter-culturing resulted in seed cotton yield of 60.74 and 64% higher than the weedy check. However, the maximum net benefit was obtained from pendimethalin + inter-culturing followed by hand weeding + inter-culturing. Based on the results observed, the use of pendimethalin + hand-weeding or hand-weeding + inter-culturing can be used to economically and effectively control weeds in cotton fields of Middle Awash areas.

Keywords: Cotton yield, efficiency, net benefit, weed management, weed density,

Introduction

Cotton (*Gossypium hirsutum* L.) is the primary cash crop for many producers in both developed and developing countries. Besides the frequently observed extensive farming, it is produced on small family farms in areas where the chance for growing other crops is very limited and per capita income is very low (Goreux, 2004). In Ethiopia, cotton plays an important role in the agricultural and industrial development of the country's economy. It offers basic raw materials to the textile industry in the domestic market or abroad (Bedane and Arkebe, 2019). However, of the country‘s total possible areas for cotton production, only about three percent is being exploited presently. Consequently, the volume of cotton produced in the country is small and the present national cotton production

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is much lower than the possible potential (Bosena et al., 2011)

Many problems have been related to the lower cotton production and productivity. Of those, weeds constitute the main biotic factor influencing cotton cultivation (Silva et al., 2016). Naturally occurring weeds in cotton production fields and their management is a major crop production challenge across the world (Culpepper, 2006; Werth et al., 2006; Berger et al., 2015; Jabran, 2016). Weeds can cause 62.43 - 96.21% seed cotton yield loss if left unweeded throughout the crop growing season (Esayas et al., 2013; Workishet et al., 2019). Similarly, several research reports show that depending on weed management practices, yield reductions can range from 10 to 90% (Morgan et al., 2001; Oerke, 2006; Dogan et al., 2015). Cotton is established slowly and is, therefore, less competitive at an early stage, thus early growth stage weed competition could significantly reduce the crop plant growth and yield (Papamichail et al., 2002). Additionally, weed enhances production costs and poses an income risk to the producers (Frisvold et al., 2009).

Research efforts on the identification of cotton weed flora and cultural and chemical control have been made by different researchers to minimize the cotton yield loss due to weed competition. Season-long weed control through the integration of chemical, mechanical, and cultural methods holds great promise in irrigated cotton. Therefore, the experiment was conducted to identify weed species composition in the study field and determine the effect of integrated weed management practices on weeds and the yield of cotton in the Middle Awash Valley of Ethiopia.

Materials and Methods

The experiment was conducted at Werer Agricultural Research Center (WARC) experimental field and Gewane cotton commercial farm during the 2017 and 2018 main cropping seasons. The cotton variety used for the study was Deltpine-90. The experiment was laid out in a Randomized Complete Block Design (RCBD) with eight treatments in three replications. Plot size was 4.5 m by 7.5 m. Treatments were hand weeding + inter-culturing, pre-irrigation + hand weeding, pendimethalin (pre-emergence herbicide) + hand weeding, pre-irrigation + inter-culturing, pendimethalin + inter-culturing, pre-irrigation + pendimethalin, pre-irrigation, and control plots. Spacing between plants and rows was 0.2 and 0.9 m, respectively. Recommended agronomic practices by Werer Agricultural Research Center were followed throughout the experimental period.

A 1 m by 1 m quadrant was used to assess weed species diversity and density. Sampling was made weekly between the 20th day to the 60th day after the crop emergence (DACE) and biweekly from the 60th day up to crop maturity. Data on yield and yield components of cotton, the number of bolls, boll weight, plant population, plant height, and seed cotton yield were collected. The number of bolls (open and unopened) was recorded before picking the seed cotton. Seed cotton yield and five bolls weight were taken at the time of seed cotton picking. Plant height and the number of plant population per quadrant were recorded after seed cotton picking. Weed control efficiency was calculated using Mani et al. (1973).

$$WCE\ (\%) = \frac{WC - WT}{WC} \times 100$$

Where, WC = Weed in the control plot and WT = Weed in the treated plot. The partial budget analysis was done using CIMMYT (1988) procedure. The partial budget analysis was done for the cost of weed management practices (hand weeding, inter-culturing, pre-irrigation cost, chemical cost, and cost of chemical application) and assumed that all the other management practices are equally applied for all the treatments. The collected data were subjected to analysis of variance using SAS statistical analysis package 9.2. When F-values were significant at $P < 0.05$ levels, means were compared by Fisher's least significant difference (LSD) test.

Result and Discussion

Species composition

A total of 40 weed species in 20 families were recorded at Werer and Gewane (Table 1). The most dominant families based on the numbers of represented weed species were Euphorbiaceae, Poaceae, Amaranthaceae, Convolvulaceae, Asteraceae, Fabaceae, Malvaceae, and Zygophyllaceae. The result indicated that the broad-leaved weed types dominated the grass and sedge weeds in the experimental field. Different researchers reported that broad-leaved weeds are dominant over grasses and sedges (Shaikh et al., 2006; Cheema et al., 2008; Patel et al, 2013; Malarkodi, 2017; Workishet et al., 2020).

Weed species density

At the early stages of cotton growth, broad-leaved weeds dominated grasses. The weed species *Boerhavia erecta* with a density of 115.1 and 65.7 plants/m^2 at Werer and Gewane, respectively was the dominant and followed by *Portulaca oleracea* with a density of 19.8 and 16.9 plants/m^2. Broad-leaved weeds *B. erecta*, *P. oleracea,* and *Corchorus trilocular* were the dominant weeds at 20 and 35 DACE. *Cyperus rotundus* was dominant both at 50 DACE and crop maturity stages (Table 2). Previous findings reported that, *Bracharia eruciform*, *B/ erecta*, *C. trilocularis*, *C. rotundus,* *Echinocloa colona, Eragrostis* spp. *Ericula fatumansis, Launaea cronut, P. oleraceae, Sorghum arundinacium, Xanthium* *strumarium*, and *Cleome viscose* were the predominant broad-leaved, grass and sedge weeds in cotton fields (Esayas et al., 2013; Malarkodi, 2017; Patel et al., 2020; Workishet et al., 2020).

Table 1. Life form and proportion (%) of weed species encountered in the experimental fields of Werer and Gewane, 2017-2018.

No.	Family	Life form	The population of species (#)	The proportion of species (%)
1	Euphorbiaceae	Herb	6	15
2	Poaceae	Grass	5	12.5
3	Amaranthaceae	Herb	5	12.5
4	Convolvulaceae	Herb	3	7.5
5	Asteraceae	Herb	3	7.5
6	Fabaceae	Shrub	2	5
7	Malvaceae	Herb	2	5
8	Zygophyllaceae	Herb	2	5
9	Cucurbitaceae	Shrub	1	2.5
10	Solanaceae	Herb	1	2.5
11	Acanthaceae	Herb	1	2.5
12	Tiliaceae	Herb	1	2.5
13	Portulacaceae	Herb	1	2.5
14	Nyctaginaceae	Herb	1	2.5
15	Commelinaceae	Herb	1	2.5
16	Chenopodiaceae	Herb	1	2.5
17	Capparideae	Herb	1	2.5
18	Polygonaceae	Shrub	1	2.5
19	Papaveraceae	Herb	1	2.5
20	Cyperaceae	Sedge	1	2.5

Weed density was higher at 20 DACE and decreased till maturity in both experimental years except in the weedy control plot. At the maturity stage, densities were higher for some treatments due to late-emerging weeds that appeared after the management practices were applied (Table 3). The highest weed density per meter square (325.1) at 20 DACE was recorded from pre-irrigation + inter-culturing treatment followed by control plot (281) and pendimethalin + hand weeding (270.3) treatments; while the least was recorded from pre-irrigation + pendimethalin (101.9) and pre-irrigation (104.9) in 2017. In 2018, the highest weed density per square meter was recorded from pre-irrigation (110.1) whereas, the least (43.7) was recorded from one-hand weeding + inter-culturing.

At 35 DACE the highest weed density was recorded from the control plot (280.6) followed by pre-irrigation (273.1) and pre-irrigation + hand weeding (238.9) treatments; while the least was recorded from pre-irrigation + pendimethalin (54.1) in 2017. In the 2018 season, pre-irrigation + inter-culturing resulted in the highest density (121.1) whereas the least

(42.5) was recorded from weeding + inter-culturing at both locations. (Table 3). The density of all weed species was highest in the weedy control plot and lowest in pendimethalin + inter-culturing as well as pre-irrigation + pendimethalin application at 20, 35, and 50 DACEs in both experimental years. Several studies have shown a significant reduction in weed density with the application of pendimethalin (Takim and Uddin, 2010; Malarkodi, 2017). Patel et al. (2013) reported lower weed density and dry matter from pendimethalin + hand weeding at 30 and 60 DAS followed by Fluchloralin 0.75 + hand weeding at 30 and 60 DAS. Malarkodi (2017) reported that lesser and comparable weed density and dry matter were recorded by the application of pendimethalin + hand weeding or pendimethalin + power weeding at 20 DAS. Similarly, Patel et al. (2020) stated that the lowest number of weeds was recorded from pendimethalin + hand weeding at 30 and 60 DAS. The mean data shows that weed density at 35 and 50 DACEs showed that hand weeding + inter-culturing followed by pendimethalin + inter-culturing resulted in the lowest weed density (Table 3). Several reports show that application of pendimethalin + one-hand weeding at 45 DAS resulted in effective control of grasses, broad-leaved weeds, and to some extent sedges due to the broad-spectrum action of the herbicide (Malarkodi, 2017; Nalini and Chinnusamy, 2019).

The highest weed control efficiency was recorded from pre-irrigation + pendimethalin (56.5%), hand weeding + inter-culturing (70.4%), and pendimethalin + inter-culturing (72.1%) at 20, 35, and 50 DACE, respectively (Table 4).

Table 2. Top 20 weed species, their density, and effect on cotton maturity period at different dates of cotton growth at Werer and Gewane in 2017 and 2018 cropping seasons.

No	Scientific name	Family	Number of individual weed species (m^{-2})							
			20 DACE*		35 DACE		50 DACE		Crop maturity	
			Werer	Gewane	Werer	Gewane	Werer	Gewane	Werer	Gewane
1	*Boerhaavia erecta*	Nyctaginaceae	115.146	65.75	71.583	11.469	28.135	28.458	5.312	2.99
2	*Portulaca oleracea*	Portulacaceae	19.781	16.938	13.427	12.615	6.385	1.26	0.51	0.542
3	*Corchorus trilocularis*	Tiliaceae	18.01	16.042	9.01	1	3.021	2.01	0.01	0
4	*Cyperuse rotundus*	Cyperaceae	14.917	13.019	5.323	6.135	18.208	20.009	79.854	69.083
5	*Lavnaea carnuta*	Compositae	9.156	5.917	7.208	11.792	10.469	9.281	11.906	10.01
6	*Diger amuricata*	Amaranthaceae	5.423	14.667	4.792	10.01	6.667	5.938	10.094	11.396
7	*Echinocloa colana*	Poacea	6.375	0.938	1.573	1.125	2.042	2.417	1.115	0.896
8	*Digitaria abyssinica*	Poacea	4.115	0.01	0.406	0.073	0.427	0.396	3.625	0
9	*Eriocloa fatmensis*	Poacea	2.635	2.635	2.708	0.99	4.104	4.229	10.021	5.313
10	*Datura stramonium*	Solanaceae	2.208	0.104	0.24	0.021	0.375	0.371	0.646	0.448
11	*Cucumis dipsaceus*	Cucurbitaceae	0.063	11.469	0.552	5.906	0	2.948	0	0.542
12	*Sorghum arundianaceum*	Poacea	0.75	0.396	2.885	0.625	2.354	2.271	7.177	2.271
13	*Oxygonum sinuatum*	Polygonaceae	0.229	3.938	0.365	3.125	0.752	1.606	2.615	52.396
14	*Acalypha crenata*	Euphorbiaceae	0.01	2.115	0.031	0.729	0.021	1.146	0.469	1.948
15	*Amaranthus viridis*	Amaranthaceae	0	0.219	0.031	1.354	0.042	0.021	0.052	0.802
16	*Euphorbia indica*	Euphorbiaceae	0.208	0.167	0.25	0.135	0.323	0.229	1.292	0.771
17	*Xanthium strumarium*	Amaranthaceae	0.052	0.552	0.345	0.865	0.146	0.198	0.271	0.385
18	*Amranthus hybridus*	Amaranthaceae	0.104	0	0.01	0.021	0.021	0.031	0.281	0.063
19	*Commelina benghalensis*	Commelinaceae	0	0	0.385	0.208	0.427	0.219	1.104	0.063
20	*Argemone ochroleuca*	Papaveraceae	0.021	0	0.061	0	0.021	0.011	0.273	0.021

* DACE = Days after crop emergence

Table 3. Effect of different weed control methods on total weed density (plant m^{-2}) at Werer and Gewane in 2017 and 2018.

No	Treatments	Weeds density (m^{-2})							
		2017				2018			
		20 DACE	35 DACE	50 DACE	Maturity	20 DACE	35 DACE	50 DACE	Maturity
1	Hand weeding + inter-culturing	209.73	70.51	68.18	153.33	43.67	42.5	46.17	64.17
2	Pre-irrigation + hand weeding	198.42	238.88	164.38	138.67	85.75	85.92	80.42	102.5
3	Pendimethalin + hand weeding	270.33	90.18	88.84	291.33	58.67	69.08	80.92	80.83
4	Pre-irrigation + inter-culturing	325.08	183.23	191.4	250.75	73.92	121.17	92.2	88.92
5	Pendimethalin +inter-culturing	157.37	64.9	53.84	332.08	64.83	48.21	56.92	68
6	Pre-irrigation + pendimethalin	101.92	54.16	92.08	195.58	53.08	93.5	96.58	93.25
7	Pre-irrigation	104.92	273.13	195.34	207.08	110.08	110.67	101.58	102.75
8	Control	281.02	280.63	217.82	190.75	81.58	104.17	192.18	96.58

Note: DACE = Days after crop emergence

Table 4. Mean weed control efficiency at different growth stages of cotton at Werer and Gewane in 2017 and 2018.

Treatments	WCE (%) at 20 DACE	WCE (%) at 35 DACE	WCE (%) at 50 DACE	WCE (%) at Maturity
Hand weeding + inter-culturing	30.08[bc]	70.38[a]	71.99[a]	47.00[b]
Pre-irrigation + hand weeding	20.15[cd]	15.25[c]	39.96[cd]	30.09[c]
Pendimethalin + hand weeding	9.61[de]	58.07[b]	58.11[b]	45.14[b]
Pre-irrigation + inter-culturing	9.97[de]	20.61[c]	30.31[d]	33.11[c]
Pendimethalin +inter-culturing	38.45[b]	70.14[a]	72.07[a]	70.57[a]
Pre-irrigation + pendimethalin	56.52[a]	61.21[b]	53.99[b]	17.83[d]
Pre-irrigation	40.27[b]	0.22[d]	51.49[bc]	2.02[e]
Control	-	-	-	-
Mean	25.63	36.98	47.24	30.72
C.V. (%)	31.83	13.23	15.84	17.92
LSD (0.05)	14.29	8.59	13.1	9.64

* WCE= Weed control efficiency, DACE= Days after crop emergence, LSD=Least Significance Difference, CV= Coefficient of Variability, Means followed by the same letter (s) within a column are not significantly different from each other at 5 % level of significance

Effect of weed management on yield and yield component of cotton

Treatments showed significant differences on plant height, number of bolls per plant, boll weight, and seed cotton (Table 5). Hand weeding + inter-culturing, pendimethalin + inter-culturing, and pendimethalin + hand weeding resulted in higher cotton height than the weedy check and pre-irrigation treatments. The highest number of boll (19.9 boll/plant) and boll weight (4.5 gm/boll) was recorded from pendimethalin + inter-culturing and) followed by hand weeding + inter-culturing with a boll number of 16.1 and boll weight of 4.5. The highest seed cotton yield was obtained from pendimethalin + inter-culturing (2.6 ton/ha) followed by hand weeding + inter-culturing (2.3 ton/ha), while the lowest (0.941 ton/ha) was from the weedy check (Table 5). Hand weeding + inter-culturing and pendimethalin + inter-culturing management treatment yielded 60.74 and 64% higher seed cotton yields than weedy check, respectively. A yield loss of 64% in seed cotton was recorded when weeds were left unweeded throughout the crop-growing season.

Related studies also showed a higher plant height and a greater number of bolls from the integrated use of pendimethalin and hand weeding (Ali, 2013; Nalini and Chinnusamy, 2019). According to Patel et al. (2013), the highest seed cotton yield was reported in weed-free conditions, followed by pendimethalin + hand weeding at 30 and 60 DAS. Similarly, different scholars reported that the application of pendimethalin + power weeding at 40 DAS could keep the weed density reasonably at a lower level and increase seed cotton yield compared to uncontrolled weeds in the cotton field (Esayas et al., 2012; Malarkodi, 2017; Nalini and Chinnusamy, 2019)

Table 5. Effect of weed management practices on cotton yield and yield components (Mean of the two locations, Werer and Gewane, and years (2017 and 2018).

Treatments	Plant height (cm)	Boll number/plant	Boll weight(gm)	Seed cotton yield (ton/ha)
Hand weeding + inter-culturing	71.92^{ab}	16.15^{ab}	4.56^{a}	2.398^{a}
Pre-irrigation + hand weeding	60.23^{bc}	12.61^{abc}	3.45^{b}	1.323^{bc}
Pendimethalin + hand weeding	62.95^{ab}	15.25^{abc}	4.05^{a}	1.927^{ab}
Pre- irrigation + inter-culturing	54.53^{bc}	10.95^{bc}	3.45^{b}	1.200^{bc}
Pendimethalin + inter-culturing	81.08^{a}	19.992^{a}	4.57^{a}	2.615^{a}
Pre- irrigation + pendimethalin	54.533^{bc}	9.01^{bc}	3.07^{b}	1.044^{bc}
Pre- irrigation	51.40^{c}	11.15^{bc}	2.33^{c}	0.960^{c}
Control	50.97^{c}	8.18^{c}	2.33^{c}	0.941^{c}
Mean	61.42	12.91	3.43	15.51
C.V. (%)	29.36	24.48	21.06	27.51
LSD (0.05)	19.73	7.85	0.59	8.93

* LSD=Least Significance Difference, CV= Coefficient of Variability, Means followed by the same letter (s) within a column are not significantly different from each other (5%).

Cost-benefit

The highest weed management cost was recorded from hand weeding + inter-culturing (4800 ETB ha^{-1}) while the lowest cost was from pre-irrigation (550 ETB ha^{-1}). The maximum net return was recorded from pendimethalin + inter-culturing (94,403.5 ETB ha^{-1}) followed by hand weeding + inter-culturing (83,686.2 ETB ha^{-1}) (Table 6).

Table 6. Cost-benefit analysis of the different weed management practices on cotton in Middle Awash (Mean of two locations, Werer and Gewane, and years 2017 and 2018).

Treatments	Actual yield (ton/ha)	Adjusted yield (ton/ha)	Total cost (ETB*)	Gross return (ETB)	Net return (ETB)
Hand weeding + inter-culturing	2.398	2.1582	4800	88486.2	83686.2
Pre-irrigation + hand weeding	1.323	1.1907	3750	48818.7	45068.7
Pendimethalin+ hand weeding	1.927	1.7343	3690	71106.3	67416.3
Pre- irrigation + inter-culturing	1.2	1.08	2150	44280	42130
Pendimethalin+ inter-culturing	2.615	2.3535	2090	96493.5	94403.5
Pre- irrigation + pendimethalin	1.044	0.9396	1040	38523.6	37483.6
Pre- irrigation	0.96	0.864	550	35424	34874
Control	0.941	0.8469	0	34722.9	34722.9

* ETB= Ethiopian Birr

Conclusion and Recommendation

Results of this study have shown that weed density, cotton boll number, boll weight, and seed cotton yield were significantly affected by weed management practices. Hand weeding + inter-culturing and pendimethalin + inter-culturing resulted in a seed cotton yield of 60.74 and 64% higher than the weedy check. However, the maximum net benefit was obtained from pendimethalin + inter-culturing followed by hand weeding + inter-culturing. The study showed that pendimethalin + hand-weeding or hand-weeding + inter-culturing can effectively and economically control weeds in cotton fields of Middle Awash areas.

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References

Ali H., Abid S.A., Ahmad S., Sarwar N., Arooj M., Mahmood A, and Shahzad A.N. 2013. Integrated weed management in cotton cultivated in the alternate-furrow planting system. *Journal of Food, Agriculture, and Environment*, 11 (3&4): 1664 – 1669. DOI: https://doi.org/10.1234/4.2013.4916.

Bedane G. and Arkebe G.E. 2019. Cotton production potential areas, production trends, research status, gaps, and future directions of cotton improvement in Ethiopia. *Greener Journal of Agricultural Sciences*, 9(2): 163-170. http://doi.org/10.15580/GJAS.2019.2.040619064.

Berger S.T., Ferrell J.A., Rowland D.L. and Webster T.M. 2015. Palmer amaranth (*Amaranthus palmeri*) competition for water in cotton. Weed Science, 63(4): 928 – 935, DOI: https://doi.org/10.1614/WS-D-15-00062.1

Bosena T., Bekabil F, Gebremedhin B, Hoekstra D. 2011. Factors affecting cotton supply at the farm level in Metema District of Ethiopia. *Journal of Agriculture, Biotechnology and Ecology*, 4(1): 41-51. https://hdl.handle.net/10568/3392.

Cheema M.S., Nasrullah M., Akhtar M. and Ali L. 2008. Comparative efficacy of different planting methods and weed management practices on seed cotton yield. *Pakistan Journal of. Weed Science Research*, 14 (3-4): 153-159.

CIMMYT. 1988. Economics Program, International Maize and Wheat Improvement Center. *From agronomic data to farmer recommendations: An economics training manual*, (No. 27). CIMMYT.

Culpepper A.S. 2006. Glyphosate-induced weed shifts. *Weed Technology*, 20(2): 277 – 281. DOI: https://doi.org/10.1614/WT-04-155R.1

Dogan, M.N., Jabran K. and Unay A. 2015. Integrated weed management in cotton. In: Chauhan, B.S., Mahajan, G. (Eds.), Recent Advances in Weed Management. Springer,pp 197-222, DOI: 10.1007/978-1-4939-1019-9_9.

Esayas T., Abraham G.H. and Mashila D. 2012. Quantitative and qualitative determination of weeds in cotton-growing areas of Humera and Metema, Northwestern Ethiopia. *Ethiopian Journal of Applied Science and Technology*, 3(1): 57 -69. https://journals.ju.edu.et/index.php/ejast/article/view/851.

Esayas T, Abraham GH, Mashila D. 2013. Weed Interference in Cotton (Gossypium hirsutum L.) in the Middle Awash, Ethiopia. *Ethiopian Journal of Applted Science and Technology*, 4(1): 41- 49. https://journals.ju.edu.et/index.php/ejast/article/view/842.

Frisvold G.B., Hurley T.M., Mitcell P.D. 2009. Overview: herbicide-resistant crops – diffuson, benefits, pricing, and resistance management. *AgBioForum*, 12: 244-248, http://hdl.handle.net/10355/6925.

Goreux, L. 2004. Cotton after Cancun: Draft discussion paper to inform debate. http://www.acp-eu-trade.org/pdf.

Jabran K. 2016. Weed flora, yield losses, and weed control in cotton crops. *Julius-*

Kühn-Archiv, 452: 177-182: DOI: 10.5073/jka.2016.452.023

Malarkodi N. 2017. Integrated Weed Management Effect on Weeds and Seed Cotton Yield. *International Journal of Environment, Agriculture and Biotechnology*, 2(2):2456-1878, http://dx.doi.org/10.22161/ijeab/2.2.6.

Mani VS, Malla ML, Gautam KC, Bhagwndas. 1973. Weed killing chemicals in potato cultivation. Indian Farm. 22:17-18.

Morgan G.D., Baumann P.A. and Chandler J.M. 2001. Competitive impact of palmer amaranth (*Amaranthus palmeri*) on cotton (*Gossypium hirsutum*) development and yield. *Weed Technology*, 15(3):408 – 412. DOI: https://doi.org/10.1614/0890-037X(2001)015[0408:CIOPAA]2.0.CO;2.

Nalini K. and Chinnusamy C. 2019. Weed management effects on cotton growth and yield. *Indian Journal of Weed Science*, 51(1): 50-53. DOI: 10.5958/0974-8164.2019.00011.X.

Oad F.C., Siddiqui M.H., Buriro U.A. and Solangi, G.S. 2007. Weed management practices in cotton crop. *Asian Journal of Plant Sciences* 6: 344-348.

Oerke E.C. 2006. Crop losses to pest. *The Journal of Agricultural Science*, 144(1): 31 – 43. DOI: https://doi.org/10.1017/S0021859605005708.

Papamichail D., Eleftherohorinos I., Froud-Williams R. and Gravanis F. 2002. Critical periods of weed competition in cotton in Greece. *Phytoparasitica*, 30(1): 105-111.

Patel H.F, Makwana A.I., Attar S.K., Raj V.C. 2020. Effect of intra row spacing and weed management in cotton (*Gossypium hirsutum* L.) under South Gujarat conditions. *International Journal of Current Microbiology and Application Sciences*, 9(07): 3756-3765. doi: https://doi.org/10.20546/ijcmas.2020.907.440.

Patel J.G., Raj V.C., Kumar V., Sutaria C.M. and Usadadiya V.P. 2013. Integrated weed management in Bt cotton (*Gossypium hirsutum* L.). *International Journal of Agriculture Innovations and Research*, 2(2): 149-151.

Shaikh M.A,, Ahmad S, and Malik, N.A. 2006. Integrated weed management and its effect on the seed cotton yield in cotton (*Gossypium hirsutum* L.) crop. *Pakistan Journal of Weed Science Research*, 12(1/2): 111-117.

Silva M.P.D, Parreira M.C, Bressanin F.N, Alves, P.L.D.C.A. 2016. Periods of Weed Interference on Transgenic Cotton 'IMACD 6001LL'. *Revista Caatinga*, 29(2):375 – 383. DOI: 10.1590/1983-21252016v29n214rc.

Takim F.O. and Uddin II R.O. 2010. Effect of weed removal on insect populations and yield of cowpea [*Vigna unguiculata* (L) Walp]. *Australian Journal of Agricultural Engineering*, 1(5): 194-199. Available at www.sciencej.com/November2010.html

Werth J.A., Preston C., Roberts G.N. and Taylor I.N. 2006. Weed management practices in glyphosate-tolerant and conventional cotton fields in Australia. *Australian Journal of. Experimental Agriculture*, 46: 1177-1183. https://doi.org/10.1071/EA05163.

Workishet T., Mulugeta N., Miesso H., and Ibrahim H. 2020. Effect of weeding frequency on Yield of Cotton (*Gossypium hirsutum* L.) at Werer, Ethiopia. *Acadademic Research Journal of Agriultural Science Research*, 8(6): 572-577.

Workishet T., Silesh G., Zemedikun A., Nurhussien S. and Sharew A. 2019. Survey of cotton weeds in Middle Awash of Ethiopia. *Greener Journal of Agricultural Sciences*, 9(2): 259-267: http://doi.org/10.15580/GJAS.2019.2.052719103.