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Critical Time of Weed Competition and Evaluation of Weed Management Techniques on Turmeric (*Curcuma Longa*) at Tepi, South West Ethiopia

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Abstract: *Turmeric (Curcuma longa) is one of the leading exported spice crop in Ethiopia. Weeds are a major constraint in Turmeric production. Understanding the critical period for weed competition and weed management techniques can be a tool for effective weed control and reducing the impacts of weeds. The experiment was conducted during 2012 to 2013 using randomized complete block design with three replications to determine the critical period and evaluation of weed management techniques. Timing of weed removal was based on the number of days after Turmeric planted. To determine critical time of weed competition, weeds allowed competing with Turmeric for 15, 30, 45, and 60 days after planting. In addition, season long weedy check and weed-free check were included as control. For weed management study five treatments were applied which contain both hand weeding and mulching at different periods. A total of 27 weed species were identified. The most important families according to the number of represented species were Poaceae (5 species), Compositae (3 species) and Amaranthaceae (3 species). There was a highly significant difference ($p<0.1$) between treatments. When weeding was totally ignored yield loss amounted to 93.886% in 2012 and 90.55% in 2013 croping season. Number of tiller, number of leaf per tiller, plant height, leaf width and length, rhizome width and length, number of fingers per rhizome and yield were affected significantly at $p<0.001$. Maximum yield loss were obtained when weeding applied at 60 days after planting which is 51.63% in 2012 and 34.69% in 2013, whereas, minimum yield loss were obtained when wedding applied at 15, 30 and 45 days after planting which was 11.63%, 21.467% and 27.119% in 2012, whereas 1.999%, 7.656% and 8.0926% in 2013 respectively. The result reviled that yield advantage of 45.264%, 38.408 and 33.63 in 2012 and 33.36%, 29.27% and 28.94% obtained when the first hand weeding was applied at 15, 30 and 45 days after planting when compared with the treatment where the first hand weeding was applied at 60 days after planting respectively. This result clearly indicates that sever crop weed competition has taken place between 30 and 60 days. Hence, it would be wise to apply the first hand weeding between 30 and 45 days after planting or weeding at 30, 60 plus mulching plus one hand weeding as needed were good agronomic practice help to avoid the period where sever competition takes place for maximum yield of the crop.*

Keywords: *Critical, ginger, Tepi, weed.*

1. INTRODUCTION

Turmeric (*Curcuma longa*) (Family: *Zingiberaceae*) is One of exported spice in Ethiopia, southwest Ethiopia produce this spice as a cash crop and many lively hood had been depend on it for a living. Tepi national spices research center make introduction of this spices and collect a number of accession and release one variety with the name ‘’dame’’ which give yield more than 250quntal per hectare and have a good quality for export, since then farmers, investors and Government farms engaged in this sector for production and several extraction company also involve to extract essential oil and oleoresin for export. It is used as condiment, dye, drug and cosmetic.

In Ethiopia Turmeric production and productivity has been growing since the release of the variety. For instance production and productivity of turmeric in individual region shows us, 483ha and 39460 quintal, 18.1ha and 160.3 quintal and 501ha and 55611 quintal in south nation and nationality of people regional state (SNNPRS), Oromia and Amhara region respectively. Ethiopia also starts exporting this spice. for instance in 2009/2010 were 2932 tone were exported and obtained 2840000 USD and it share the total exported spice from by volume 18.91% and in value 15.37% and it ranks 2nd to ginger. In this year (2014) a big farms like Horizome bebeka estate farm and Ethiopian spices factory start exporting to Europe.

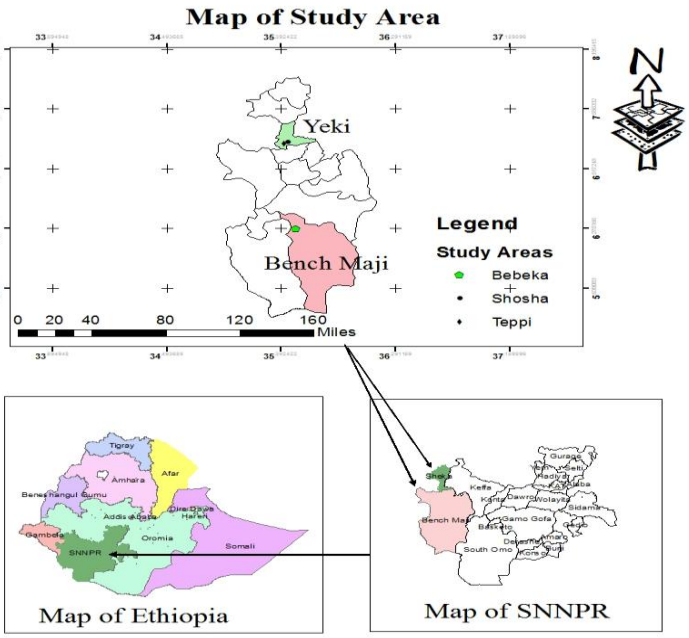
Turmeric is highly suffer for weed infestation especially for water and nutrient competition, south west part of the country characterized as high weed diversity and fast weed growing which make weed control difficult. Competition from weeds is the most important of all biological factors that reduce agricultural crop yield, this is due to weeds are the most competent for nutrient, water, and sun light. The magnitude of yield loss is affected by many agronomic and environmental factors, but most importantly by the weed density, and time of emergence relative to the crop. As a general rule, an average weed infestation may be expected to reduce yields by 10 - 15% (Woolley *et al*., 1993).

Understanding the critical period for weed control (CPWC) can be a tool for effective weed control and reducing the impacts of weeds (Weaver and Tan, 1987). It is an integral part of integrated weed management (IWM) and can be considered the first step to design weed control strategy (Zimdahl, 2004). The CPWC is the period of crop life cycle during which weeds must be controlled to prevent unacceptable or economic yield loss **(**Evans et al, 1980 and Zimdahl *et al*., 2003)**.** The length of the critical period of weed control may vary depending on the acceptable yield loss first proposed in corn (Hall *et al*., 1992), and later in soybean and white bean (*Phaseolus vulgaris* L.) (Woolley *et al*., 1993).

The critical period of weed control for canola is around the 4-leaf stage, or 17-38 days after crop emergence (Martin et al., 2001). For pea varied between sites but began as early as 2 weeks after emergence (Harker *et al*., 2001). For a more competitive crop such as barley the timing of weed removal is not as clear cut (O'Donovan *et al*., 2005). For corn, the critical period depends on nitrogen availability, with the critical period becoming shorter with increased fertilizer rates. Critical period was determined as 7–49 days after seeding in off-season and 7–53 days in main season to achieve 95% of weed-free yield, and 23–40 days in off-season and 21–43 days in main season to achieve 90% of weed-free yield in aerobic rice (Anwar *et al*., 2012), leek should be kept weed free between 7 days and 85 days after transplanting to avoid yield losses in excess of 5% (Tursun *et al*., 2007). Many findings suggested that critical time of weed competition vary from crop to crop and area to area. The present study seek to identify which time in the growth of turmeric most susceptible for weed competition and result significant yield loss and determine weed management technique which is suitable, economical and effective.

2. MATERIALS AND METHODS

2.1. Experimental Site and Soil



The trial was conducted starting from 2010 to 2012 in Tepi National spices research center which is 611km away from Addis Ababa, and located at Latitude: 7^0 3' N Longitude: 35^0, 0'E with altitude of 1200 m. Maximum and minimum temperature are 30^0C and 15^0C respectively. Mean annual rain fall of the area is 1591mm; it is under hot to warm humid lowland agro ecology (EIAR, 2012). Soils of the area are very deep (>150cm) and have a color of dark brown (7.5YR3/2) when moist. The texture

is clay with moderate medium sub angular blocky structure. The pH (H_2O) of surface soil is 7.7, decreasing to 5.8 in subsurface horizon. The organic matter content is medium to very high (2.47 to 7.02%) and the total nitrogen content is low to very high (0.09 to 0.73%); while available phosphorous is low to medium (0.97 to 7.36ppm). available micronutrients range between 1.1 to 6.92 ppm for Fe, 51 to 111.7ppm for Mn, 1.96 to 5.16ppm for Zn and trace to 2.46 ppm for Cu.

2.2. Plant Material

Turmeric variety "Dame" was used for the study. This variety was selected because of it is widely grown in south west Ethiopia and it is highly affected by weed completion

2.3. Experimental Treatments and Design

The experimental design was a randomized complete block with three replications. To determine CPWC and evaluation of weed management technique. Timing of weed removal was based on the number of days after Turmeric planted. To determine CPWC, allowing the weeds to compete with Turmeric for 15, 30, 45, and 60 days after planting In addition, season long weedy check and weed-free check were included as control. For weed management study 5 treatment were applied which contain both hand weeding and mulching applying at different period (mulching at planting + weeding at 45, and 75 days; mulching at planting + weeding at 60 and 90 days; weeding at 30 + mulching + two hand weeding as needed; weeding at 30, 60 + mulching + one hand weeding as needed; weeding at 45, 75 + mulching + one hand weeding as needed. We were use vetiver (*Chrysopogon zizanioides*)) grass as a mulch material. Planting and other agronomic practice were done according to Girma *et al*., (2008) recommendation.

2.4. Data Collection

At each weed removal time, a 50 cm × 50 cm quadrate was randomly placed lengthwise at four spots in each plot for recording weed data. Weeds were clipped to ground level, identified and counted by species and List of the noxious and important weed species were summarized in a table. Fresh weight of individual weed species were measure and their correlation with other vegetative and yield related parameter were determined. From the crop, number of tiller per stand, number of leaf per tiller, leaf length, leaf width, rhizome length, rhizome width, number of finger per rhizome and fresh yield kilogram per plot were measured

2.5. Statistical Analysis

Statistical Analysis System (SAS 9.1) software was used to analyze the data. For each year, mean yield and measured vegetative parameter across the three blocks was calculated for each treatment. The yield data converted to percentage values (relative yield, RY) of the season long weed-free control in each treatment group. Person correlation coefficient were used to obtain the association of each parameter

3. RESULT AND DISCUSSION

A total of 27 weed species were identified (tale.1.) The most important families according to the number of represented species were *Gramineae* (5 species), *Compositae* (3 species) and *Amarantha e* (3 species), All noxious and important weed species were abundantly growing in the experimental site and the surrounding. The classification as noxious and important was based on the species competitive ability and time and money spent for their control. The noxious species are highly competitive for essential growth requirements and are also too difficult to control once they are established in the field.

There was a highly significant difference ($p<0.1$) between treatments (Table2). The result clearly demonstrated that turmeric was very poor competitor of weeds that as weeding was delayed tremendous yield loss was incurred. When weeding was totally ignored yield loss amounted to 93.886% in 2012 and 90.546% in 2013. From the result number of tiller, number of leaf per tiller, plant height, leaf width and length, rhizome width and length, number of fingers per rhizome and yield were affected significantly at $p<0.001$. from the treatment weeding starts at 15, 30, and 45 days after planting were found Significantly different to that of weeding starts at 60 days after planting,

Maximum yield loss were obtained when weeding applied at 60 days after planting which is 51.63% in 2012 and 34.69% in 2013 whereas, minimum yield loss were obtained when wedding applied at 15, 30 and 45 days after planting which was 11.63%, 21.467% and 27.119% in 2012, whereas 1.999%, 7.656% and 8.0926% in 2013 respectively. The result reviled that yield advantage of 45.264%, 38.408 and 33.63 in 2012 and 33.36%, 29.27% and 28.94% obtained when the first hand weeding was applied at 15, 30 and 45 days after planting when compared with the treatment where the first hand weeding was applied at 60 days after planting respectively. This result clearly indicates that sever crop weed competition has taken place between 30 and 60 days. Hence, it would be wise to apply the first hand weeding between 30 and 45 days after planting in order to avoid the period where sever competition takes place for maximum yield of the crop.

Table. 1. *Weed composition in Turmeric experimental field during 2010 and 2012*

SN.	Botanical Name	Family	Characteristics	Economic importance
1	*Sida alba*	*Malvaceae*	A/P	Noxious
2	*Galinsoga parviflora*	*Compositae*	A	Important
3	*Mimosa pudica*	*Mimosaceae*	P	Noxious
4	*Commelina benghalensis*	*Commelinaceae*	A/P	Noxious
5	*Bidens pilosa*	*Compositae*	A	Important
6	*Euphorbia heterophylla L*	*Euphorbiaceae*	A	
7	*Achyranthus aspera.*	*Amaranthaceae*	A/P	
8	*Oplismenus hirtellus*	*Gramineae*	P	
9	*cyperus esculentus*	*Cyperaceae*	P	Noxious
10	*Galium spurium L. Var. africanum Verdc*	*Rubiaceae*	A	
11	*Oxigonum sinuatum(Meisn.) Dammer*	*Polygonaceae*	A	
12	*Amaranthus hybridus L*	*Amaranthaceae*	A	
13	*oxalis corniculata L*	*Oxalidaceae*	A	
14	*Eriocloa fatmensis (Hochst. & Steud.) W.D. clayton*	*Gramineae*	A	
15	*Convolvulus arvensis L*	*Convolvulaceae*	P	
16	*Snowdenia polystachya (Fresen) pilg*	*Gramineae*	A	
17	*Amaranthus spinosus L*	*Amaranthaceae*	A	
18	*Chenopodium procerum (Hochst ex.) Moq.*	*Chenopodiaceae*	A	
19	*Cerastium arvense*	*Caryophyllaceae*	A	
20	*Cynodon dactylon*	*Chlorideae*	P	Noxious
21	*Tagetes minuta L.*	*Compositae*	A	
22	*Rottboellia cochinchinensis (Lour.) W.D.Clayton*	*Gramineae*	A	
23	*Eleusine Indica (L) Goertn*	*Gramineae*	A	
24	*Rumex abyssinicus Jacq*	*Polygonaceae*	P	
25	*Leucas martinicensis (Jacq.) Ait.f.*	*Labiatae*	A	
26	*Cuscuta campestris Yunker*	*Convolvulaeae*	A/P	
27	*Solanum nigrum L.*	*Solanaceae*	A	

A= annual, P= Perennial

Table.2. *Mean of vegetative and yield data and their mean separation 2012.*

Treatment	Tiller per plant Mean	Plant height	Leaf per tiller	Leaf length	Leaf width	Rhizome length	Rhizome width	Finger per rhizome	Yield kilogram per plot	% age Yield loss of clean weeding
T1	$6.2000A^{BC}$	57.200^{BC}	7.0667^{AB}	28.933^{AB}	11.3733^{AB}	12.667^{A}	15.800^{A}	8.400^{A}	54.200^{A}	11.63
T2	6.8000^{A}	59.527^{ABC}	6.8000^{ABC}	30.933^{AB}	10.6933^{ABC}	13.467^{A}	14.000^{A}	8.533^{A}	48.167^{A}	21.467
T3	6.6000^{AB}	56.620^{BC}	6.3333^{ABC}	29.213^{AB}	$9.9667B^{C}$	12.400^{A}	13.667^{A}	7.933^{A}	44.700^{AB}	27.119
T4	4.9333^{BC}	52.467^{C}	6.2000^{BC}	26.147^{B}	9.8200^{C}	13.067^{A}	15.067^{A}	9.067^{A}	29.667^{B}	51.63
T5	4.8000^{BC}	60.867^{ABC}	6.4000^{ABC}	29.667^{AB}	11.2067^{ABC}	12.533^{A}	13.133^{A}	10.933^{A}	47.250^{A}	22.962
T6	4.9333^{BC}	66.400^{AB}	6.4667^{ABC}	33.927^{A}	11.1400^{ABC}	12.400^{A}	14.667^{A}	10.133^{A}	30.333^{B}	50.544
T7	4.5333^{C}	69.333^{A}	6.6667^{ABC}	33.333^{A}	11.8467^{A}	11.667^{A}	14.400^{A}	7.400^{A}	48.833^{A}	20.381
T8	4.4000^{C}	68.340^{A}	6.3333^{ABC}	30.353^{AB}	11.4400^{A}	11.400^{A}	16.267^{A}	8.533^{A}	51.200^{A}	16.5213
T9	5.6000^{ABC}	61.000^{ABC}	6.0667^{C}	30.360^{AB}	11.2933^{AB}	11.200^{A}	14.067^{A}	8.733^{A}	50.250^{A}	18.07
T10	5.8667^{ABC}	55.533^{C}	7.2000^{A}	28.800^{AB}	10.8733^{ABC}	12.067^{A}	14.867^{A}	9.067^{A}	61.333^{A}	0
T11	0.7850^{D}	14.333^{D}	1.1667^{D}	16.100^{C}	5.067^{D}	5.0000^{B}	5.100^{B}	5.100^{B}	3.750^{C}	93.886
CV%	21.496	11.394	9.1472	12.0703	8.6473	12.864	20.34	25.40	23.309	
LSD5%	1.82	10.714		5.638	1.468	2.497	4.676	3.5355	16.266	

All mulching and hand weeding treatment on turmeric reviled that they are efficient in controlling weed and gain yield advantage almost similar to clean weed treatment, so Appling mulch after removal of weed in between 30 and 45 days after planting was found good agronomic practice.

Mulching turmeric at planting or after two hand weddings the frequency of hand weeding can be reduced and cost of weeding minimized. In addition to the advantage of mulching turmeric for controlling weeds, mulching at planting has enhanced early germination and growth of turmeric compared with un-mulched treatments. This might be attributed to the regulation of the mulch on soil moisture and temperature making suitable for early germination of the crop.

Since the mulching and hand weeding treatment gives similar result reduced weeding frequency, need to chosen the best alternative weed control which reduce weeding frequency and gives comparable yield, since frequent weeding results high cost

Mulching apart from reducing the frequency of hand weeding also covers the soil and protects the rhizomes from sun light exposure which can seriously affect the quality of the crop. This finding has far reaching implication that farmers can mulch turmeric in between 30 and 45 days after planting and can delay weeding turmeric at busy times to do other farm activities without yield being affected.

(A) (B)

(B) (D)

Figure.1. *A-D, shows how effectively mulching of turmeric reduce weed competition*

Weed competition were found significantly affect vegetative, yield and yield related parameters. Tiller per plant, plant height, leaf per tiller, leaf length, leaf width, rhizome length, rhizome width, finger per rhizome and yield were found a significant negative association to that of weed biomass.

(table3).

Table.3. *Mean of vegetative and yield data and their mean separation 2013.*

Treatment	Tiller per plant Mean	Plant height	Leaf per tiller	Leaf length	Leaf width	Rhizome length	Rhizome width	Finger per rhizome	Yield kilogram per plot	% age Yield loss of clean weeding
T1	2.3867^{A}	47.433^{A}	2.5500^{A}	37.233^{A}	12.887^{A}	11.9333^{A}	14.467^{A}	11.400^{AB}	52.267^{A}	1.998762
T2	2.3433^{A}	48.197^{A}	2.6050^{A}	34.833^{A}	12.213^{A}	12.9333^{A}	14.967^{A}	18.167^{A}	49.250^{AB}	7.655673
T3	2.3400^{A}	46.643^{A}	2.5917^{A}	35.507^{A}	12.383^{A}	12.4667^{A}	14.067^{A}	15.867^{AB}	49.017^{AB}	8.092551
T4	2.3267^{A}	42.167^{A}	2.5350^{A}	31.340^{A}	11.110^{A}	13.2667^{A}	14.967^{A}	17.100^{AB}	34.833^{C}	34.68772
T5	2.3200^{A}	51.267^{A}	2.5617^{A}	37.567^{A}	12.870^{A}	12.7000^{A}	14.767^{A}	19.200^{A}	48.792^{AB}	8.514428
T6	2.3200^{A}	50.600^{A}	2.5150^{A}	36.963^{A}	11.870^{A}	12.7333^{A}	15.667^{A}	16.233^{AB}	37.667^{BC}	29.37393
T7	2.2917^{A}	52.167^{A}	2.5767^{A}	37.867^{A}	12.757^{A}	11.7667^{A}	14.900^{A}	13.433^{AB}	45.917^{ABC}	13.90509
T8	2.2250^{A}	53.237^{A}	2.5417^{A}	36.343^{A}	13.053^{A}	11.8333^{A}	16.000^{A}	16.100^{AB}	51.100^{AB}	4.186901
T9	2.1517^{A}	48.900^{A}	2.4000^{A}	38.080^{A}	12.713^{A}	11.7000^{A}	14.467^{A}	13.867^{AB}	49.958^{AB}	6.328165
T10	2.0933^{A}	44.600^{A}	2.6517^{A}	35.167^{A}	12.303^{A}	12.4333^{A}	14.367^{A}	14.600^{AB}	53.333^{A}	0
T11	0.7850^{B}	14.333^{B}	1.1667^{B}	16.100^{B}	5.067^{B}	5.0000^{B}	5.100^{B}	5.100^{B}	5.042^{D}	90.54619
CV%	16.74	33.17	16.925	27.33	21.77	12.67	17.63	55.63	20.699	
LSD5%	0.554	23.236	0.634	14.45	3.94	2.287	3.801	12.57	13.677	

**Treatment Description*

T1: weeding at 15,30,45,60,75,90,105,120,135,150,165 and 180 days after planting (12 weeding)

T2: weeding at 30, 60, 90,120, and 180 days after planting (6weeding)

T3: weeding at 45, 75, 105 and 135 and 165 days after planting (5weeding)

T4: weeding at 60, 90, and 120 and 150 days after planting (4weeding)

T5: mulching at planting + weeding at 45, and 75 days

T6: mulching at planting + weeding at 60 and 90 days

T7: weeding at 30 + mulching + two hand weeding as needed

T8: weeding at 30, 60 + mulching + one hand weeding as needed

T9: weeding at 45, 75 + mulching + one hand weeding as needed

T10: clean weeding (plots will be weed free all year round)

T11: un-weeded

Table 4. *correlation result of weed management trial of turmeric.*

Correlations												
		TPP	PH	LPT	LL	LW	RL	RW	FPR	YKGPP	YQPH	WBMAS
TPP	Pearson Correlation	1	.837**	.910**	.863**	.875**	.960**	.904**	.801**	.840**	.840**	-.931**
	Sig.(2-tailed)		.001	.000	.001	.000	.000	.000	.003	.001	.001	.000
PH	Pearson Correlation	.837**	1	.900**	.978**	.976**	.891**	.966**	.787**	.919**	.919**	-.935**
	Sig.(2-tailed)	.001		.000	.000	.000	.000	.000	.004	.000	.000	.000
LPT	Pearson Correlation	.910**	.900**	1	.893**	.931**	.958**	.938**	.816**	.894**	.894**	-.965**
	Sig.(2-tailed)	.000	.000		.000	.000	.000	.000	.002	.000	.000	.000
LL	Pearson Correlation	.863**	.978**	.893**	1	.984**	.877**	.936**	.717*	.941**	.941**	-.941**
	Sig. (2-tailed)	.001	.000	.000		.000	.000	.000	.013	.000	.000	.000
LW	Pearson Correlation	.875**	.976**	.931**	.984**	1	.901**	.951**	.749**	.974**	.974**	-.973**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.008	.000	.000	.000
RL	Pearson Correlation	.960**	.891**	.958**	.877**	.901**	1	.958**	.892**	.835**	.835**	-.953**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000	.001	.001	.000
RW	Pearson Correlation	.904**	.966**	.938**	.936**	.951**	.958**	1	.837**	.878**	.878**	-.961**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.001	.000	.000	.000
FPR	Pearson Correlation	.801**	.787**	.816**	.717*	.749**	.892**	.837**	1	.686*	.686*	-.783**
	Sig. (2-tailed)	.003	.004	.002	.013	.008	.000	.001		.020	.020	.004
YKGPP	Pearson Correlation	.840**	.919**	.894**	.941**	.974**	.835**	.878**	.686*	1	1.000**	-.943**
	Sig. (2-tailed)	.001	.000	.000	.000	.000	.001	.000	.020		.000	.000

YQPH	Pearson Correlation	.840**	.919**	.894**	.941**	.974**	.835**	.878**	.686*	1.000**	1	-.943**
	Sig. (2-tailed)	.001	.000	.000	.000	.000	.001	.000	.020	.000		.000
WBMAS	Pearson Correlation	-.931**	-.935**	-.965**	-.941**	-.973**	-.953**	-.961**	-.783**	-.943**	-.943**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.004	.000	.000	
**. Correlation is significant at the 0.01 level (2-tailed).												
*. Correlation is significant at the 0.05 level (2-tailed).												

4. CONCLUSION AND RECOMMENDATION

This result clearly indicates that sever crop weed competition has taken place when weeding delayed more than 45 days after planting. Hence, it would be wise to apply the first hand weeding between 30 and 45 days after planting or weeding at 30, 60 plus mulching plus one hand weeding as needed were found good agronomic practice and save up to 40% yield and help to avoid the period where sever competition takes place for maximum yield of the crop.

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