OPTIMIZING TILLAGE AND IRRIGATION FOR SUNFLOWER CULTIVATION IN RICE FALLOW* ALFISOLS OF SEMIARID TROPICS

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SUMMARY

Studies were conducted on sandy clay loam soil (Typic Haplustalf) to evaluate the effect of five different tillage practices versus four irrigation regimes, 60 mm irrigation at IW/CPE=0.6, 0.8, 1.0 and 1.2, and their interaction on soil physical changes and performance of sunflower (*Helianthus annuus* L.) under rice fallow condition. Tillage in general had more positive effect on seedling emergence, growth and yield of sunflower than zero tillage in puddle rice fallows. Deep primary tillage with tractor-drawn disc plow or MB plow produced significantly larger heads with higher test weight, however, secondary tillage with rotavator, either power-tiller- or tractor-drawn, made finer tilth and recorded significantly higher seedling emergence (80.7%). Tillage with tractor-drawn disc plow + rotavator (deep-fine tillage) gave significantly higher mean seed yield (1311 kg ha⁻¹) over tractor-drawn MB plow + tractor-drawn cultivator - deep tillage (1172 kg ha⁻¹), ox-drawn desi plow + power-tiller-operated rotavator - shallow fine tillage (1054 kg ha⁻¹) and ox-drawn desi plow + ox-drawn cultivator - shallow tillage (931 kg ha⁻¹). The irrigation regime at IW/CPE=1.2 recorded higher seed yield than IW/CPE=0.6, 0.8 and 1.0. Water use (ETa) by sunflower increased with increase in intensity of tillage and irrigation. WUE was higher in deep tillage practices and in irrigation regime of IW/CPE=0.8. Deep tillage, besides saving 18% of irrigation water, resulted in about 24% higher sunflower seed yield compared with shallow tillage. Interaction effects revealed that significantly higher sunflower growth and yields (both seed and oil) was realized when tillage was done with tractor-drawn disc plow + rotavator coupled with scheduling irrigations at IW/CPE=1.0 or 1.2. Tillage with two passages of country plow + once with power-tiller-operated rotavator and scheduling irrigation at IW/CPE=1.2 produced significantly superior yields of sunflower than farmers' practice.

* Massive soil structural condition after low land paddy cultivation

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Key words: tillage, irrigation regimes, water use, water use efficiency, rice fallow - sunflower

INTRODUCTION

Rice is a staple food in south India (semi-arid tropic climate). It is widely grown under irrigated and rainfed conditions in rainy season. During post-rainy season, rice is grown as second crop under controlled irrigation. However, irrigation water has become scarce of late, especially in tail-end areas of most of the irrigation zones of all major river-systems. For obvious reasons, the government and scientists encourage farmers to cultivate dry crops during post-rainy season in irrigated rice fallows. As the country is facing a shortage of vegetable oils and the oil imports touched \$800 millions (Damodaram and Hegde, 2000), it is more pragmatic to encourage oilseed crops. Sunflower (*Helianthus annuus* L.), a relatively photo-insensitive short-duration oilseed crop is fast emerging as a very promising succeeding crop to kharif rice in large parts of South India. Land preparation for the preceding crop (puddle rice) however, disturbs the soil structure and associated soil physical characteristics mainly due to the practice which has a negative impact on the performance of the next crop right from the commencement of seedling emergence (Prihar *et al.*, 1985 and Singa Rao *et al.*, 1995). This restricts the yield potential of the crop (Reddy and Reddy, 1989). The problem is ameliorated to a considerable extent by loosening the soil by tillage (Bennie and Botha, 1986). Various tillage practices and irrigation levels have been tried for different crops, however, information on interaction effects of tillage practices and irrigation regimes for sunflower in rice fallows are not available. The present study aims at examining the suitable land preparatory tillage practices and their interactions with various irrigation regimes with the key objective of identifying a tillage system and irrigation regime best suitable for sunflower in rice fallow situations.

MATERIALS AND METHODS

Field experiments were conducted on transplanted lowland rice fallow at the University Experimental Farm, Acharya N.G. Ranga Agricultural University, Hyderabad (17°19' north latitude and 78°28' east longitude and an altitude of 535 m above MSL)-a semi-arid tropic climate, during *rabi* for two consecutive years (1998 and 1999). The soil (Typic Haplustalf) was medium deep (50 cm), sandy clay loam with 66.00, 12.33 and 21.67% of sand, silt and clay, respectively, with initial bulk densities of 1.47 (0-15cm), 1.55 (15-30cm), 1.59 (30-45cm) Mg m⁻³. The moisture percentages at -0.03 MPa and -1.5 MPa pressure were 16.65 and 5.40 by weight, respectively. The soil was neutral (pH 7.54), non-saline (E.C. 0.174 d Sm⁻¹), medium in organic carbon (0.55%), low in available nitrogen (223 kg/ha) and phosphorus (21.4 kg P₂O₅/ha) and medium in available potassium (287 kg K₂O/ha).

The experiment was laid in a strip plot (6.6 m $\times$ 4.5 m) design with five tillage treatments: T₁- zero tillage (dibbling of seeds), T₂- two passages with each, ox-drawn desi plow + bullock-drawn three-tine cultivator- *farmers' practice*, T₃- two passages of ox-drawn desi plow + one passage of power-tiller-drawn rotavator (modified farmers' practice), T₄- one passage of tractor-drawn MB plow + two passages of tractor-drawn cultivator and T₅- one passage with each, tractor-drawn disc plow + rotavator, and four levels of irrigation regime of 60 mm irrigation at IW/CPE ratio of 0.6 (I₁), 0.8 (I₂), 1.0 (I₃) and 1.2 (I₄) superimposed on tillage treatments. The treatments were replicated thrice. Tillage treatments were carried out at around 10% soil moisture content thereby avoiding compaction during tillage operations. The crop (the cultivar Morden) with plant-to-plant and row-to-row distances of 45 cm and 30 cm, respectively, received 60 kg N (urea in two equal splits as basal dose and at buttoning stage), 60 kg P₂O₅ (SSP as basal dose) and 30 kg K₂O (MoP as basal dose).

Seedling emergence was determined by counting the number of newly emerged seedlings (hills) each in total plot daily. The mean weekly pan evaporation ranged from 4.2 to 8.6 mm/day (average 6.32) and 4.5 to 9.1 mm/day (average 6.72) during crop growth period of 1997-98 and 1998-99, respectively. However, there was no precipitation during the crop growing seasons. The mean weekly maximum and minimum temperatures during the crop period ranged from 38.1°C to 31.9°C and 22.0°C to 16.9°C and from 41.3°C to 31.7°C and 27.0°C to 14.6°C during 1997-98 and 1998-99, respectively. The mean relative humidity ranged from 89 to 63 and 85 to 52% during crop growth periods of the first and second years, respectively. The mean weekly bright sunshine hours varied from 10.9 to 9.0 during 1997-98 and from 10.7 to 7.7 during 1998-99.

The IW/CPE ratios of 0.6, 0.8, 1.0 and 1.2 received 4, 6, 8 and 9 irrigations during 1997-98 with total amounts of irrigation water of 240, 360, 480 and 540 mm, respectively, while during 1998-99 the same treatments were provided 5, 7, 9 and 11 irrigations with total quantities of 300, 420, 540 and 600 mm irrigation water, respectively. To minimize the interference of water from one treatment to another, 50 cm wide drains and successive 50 cm levees were constructed in between the plots. Irrigation water was applied according to the treatments and measured by V-notch weirs. Soil water availability at different soil depths was monitored by determining soil moisture content gravimetrically at three depths up to 45 cm of soil using a core sampler (Michael *et al.*, 1977) just before and 24 h after irrigation. LAI was determined with a planimeter. Growth was expressed in terms of LAI and dry matter (aboveground parts) at harvest. The heads in each net plot were harvested and threshed separately (this was carried out manually). The harvests with border rows eliminated, were threshed, dried to 10% moisture content and weighed. Oil yield was computed from seed yield and oil content. The experimental data were subjected to the analysis of variance (Panse and Sukathme, 1965).

RESULTS AND DISCUSSION

Seedling emergence

High seedling emergence with rotavator tillage (as secondary tillage) may be attributed to the formation of fine tilth resulting in improved seed-soil-water contact and soil physical conditions that are prerequisites for germination and emergence (Table 1). Similar was the case with rotavator used for secondary tillage (81.81% in case of T_5 and 79.73 in case of T_3) compared with cultivator (67.1% in case of T_4 and 65.86% in case of T_2) and zero tillage plots (57.5%). The effect of irrigation regimes and their interaction with tillage was not significant for seedling emergence.

Table 1: Effect of tillage practices and irrigation regimes on plant stand, leaf area index (LAI), head diameter and 1000-seed weight of sunflower in rice fallow

Treatment	Seedling emergence (%)		Leaf area index (at flowering)		Head diameter (cm)		1000-seed weight (g)	
	97-98	98-99	97-98	98-99	97-98	98-99	97-98	98-99
Tillage practice (T)								
T_1	58.64	56.36	1.78	1.74	11.5	10.7	35.53	34.69
T_2	66.36	65.36	2.09	2.07	13.5	13.1	37.21	36.99
T_3	79.10	80.45	2.50	2.36	14.1	13.7	37.93	38.04
T_4	68.18	66.00	2.74	2.60	16.4	16.0	40.96	40.23
T_5	80.91	82.72	3.02	2.86	16.1	15.7	41.62	40.28
Irrigation regime (M)								
I_1	69.42	69.72	1.93	1.87	12.6	11.8	34.62	34.87
I_2	71.65	72.33	2.35	2.23	13.9	13.2	37.22	37.58
I_3	71.29	70.29	2.67	2.55	15.2	14.8	40.25	39.10
I_4	70.23	68.38	2.77	2.67	15.7	15.6	42.51	40.63
CD (P=0.05)								
T	4.88	4.52	0.17	0.26	0.63	1.00	1.50	1.09
M	NS	NS	0.21	0.18	0.53	0.91	0.95	1.21

T_1 - zero tillage (dibbling of seeds),

T_2 - two passages of each, ox-drawn desi plow + ox-drawn three-tine cultivator (farmers' practice),

T_3 - two passages of ox-drawn desi plow + one passage of power-tiller-drawn rotavator (modified farmers' practice),

T_4 - one passage of tractor-drawn MB plow + two passages of tractor-drawn cultivator,

T_5 - one passage of tractor-drawn disc plow + rotavator

Irrigation regimes of 60 mm irrigation at IW/CPE ratio of 0.6 (I_1), 0.8 (I_2), 1.0 (I_3) and 1.2 (I_4)

Leaf area index

Tillage, irrigation regimes and their interaction affected the leaf area index of sunflower (Table 1). At 60 DAS, higher leaf area index (LAI) resulted when the soil was tilled to deeper depths and made to fine tilth (T_5) as compared with the other treatments. Finer tilth coupled with deep plowing (T_5) resulted in higher plant population (Table 1) and higher plant growth producing high leaf area index. Similar results were reported for mungbean (IARI, 1984) and groundnut (Khan, 1984). Irri-

gation given at shorter intervals by adopting relatively higher irrigation regimes (IW/CPE=1.0 and 1.2) resulted in higher leaf area index compared with the schedules at longer intervals (IW/CPE=0.6 and 0.8).

Size of sunflower heads

Significantly largest mean head size of 16.2 cm was registered (Table 1) in deep tillage with tractor-drawn MB plow + cultivator (T_4) which was almost similar to tractor-drawn disc plow + rotavator (T_5). Sunflower root extension to deeper soil layers and increased soil water retention under deep tillage practices, which in turn resulted in higher crop growth, was responsible for the production of larger heads. The irrigation scheduled at IW/CPE=1.2 (I_4) registered significantly large heads mainly due to optimum water supply in that particular schedule. Increase in sunflower head size with intensity of irrigation frequency was also reported earlier (Paul and Yadav, 1974; Singh *et al.*, 1995).

1000-seed weight

Both tillage practices and soil moisture regimes significantly affected sunflower seed test weight. The test weight was significantly superior in deep tillage practices (T_4 and T_5) compared with shallow tillages (T_2 and T_3) and zero tillage (T_1). Wettest soil moisture regime (I_4) produced significantly higher test weight than the others (I_1 , I_2 and I_3). Sufficient water availability in deep tillage practices and intensive irrigation regimes facilitated proper translocation of photosynthates resulting in proper seed filing and in turn higher 1000-seed weight. The results are in conformity with those of Singh *et al.* (1995).

Total dry matter accumulation

Favorable soil conditions, *i.e.*, deep-fine tillage, and high available moisture capacity created with tractor-drawn disc plow once + rotovator twice (T_5) resulted in high dry matter accumulation (Table 2). Increase in irrigation regime from IW/CPE 0.6 to 1.2 significantly increased the dry matter accumulation. This could be attributed to the availability of relatively high water level in the soil throughout irrigation cycles in the plots irrigated with IW/CPE ratios of 1.0 and 1.2. On the other hand, in IW/CPE=0.8 and IW/CPE=0.6 moisture regimes, growing plants experienced relatively high soil water stress, hence the lower dry matter accumulation. The interaction effects of tillage and irrigation regimes significantly affected the dry matter production, which appears to be due to high seedling emergence and relatively better growth at the initial stage of crop in deep-fine tillage (T_5) coupled with frequent water supply (IW/CPE ratios of 1.2 and 1.0).

Seed and oil yield

The tillage treatment with tractor-drawn disc plow once + rotovator (T_5) produced on average 80, 40, 25 and 14% higher seed yield over zero tillage (T_1), ox-

Table 2: Effect of tillage practices and irrigation regimes on dry matter (at harvest), seed yield and oil yield sunflower under rice fallows

	1997- 1998					1998- 1999				
	Irrigation regime					Irrigation regime				
	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean
Tillage (T)	Dry matter kg ha ⁻¹									
T ₁	1626	1952	2131	2178	1973	1536	1746	2040	2168	1872
T ₂	1847	2280	2576	2664	2342	1802	2195	2490	2639	2281
T ₃	2087	2580	2857	2952	2619	1993	2527	2862	3036	2604
T ₄	2210	2706	3065	3154	2745	2253	2767	3052	3101	2793
T ₅	2490	3079	3465	3545	3145	2493	2990	3287	3407	3044
Mean	2052	2522	2810	2899		2015	2445	2743	2870	
	Seed yield kg ha ⁻¹									
T ₁	557	742	838	876	753	510	633	767	834	686
T ₂	693	924	1097	1156	967	651	838	1004	1085	894
T ₃	774	1036	1228	1305	1086	718	975	1158	1256	1022
T ₄	881	1176	1315	1398	1192	851	1131	1285	1341	1152
T ₅	996	1321	1528	1584	1357	944	1248	1392	1478	1265
Mean	780	1040	1201	1264		735	965	1121	1199	
	Oil yield kg ha ⁻¹									
T ₁	200	270	312	331	278	174	225	280	309	247
T ₂	254	345	433	490	373	234	310	389	428	340
T ₃	281	395	494	532	426	261	366	449	499	394
T ₄	346	490	561	597	499	323	453	531	556	466
T ₅	394	532	650	676	566	359	504	570	611	511
Mean	295	407	492	519		270	372	444	481	

T₁- zero tillage (dibbling of seeds),T₂- two passages of each, ox-drawn desi plow + ox-drawn three-tine cultivator (farmers' practice),T₃- two passages of ox-drawn desi plow + one passage of power-tiller-drawn rotavator (modified farmers' practice),T₄- one passage of tractor-drawn MB plow + two passages of tractor-drawn cultivator,T₅- one passage of tractor-drawn disc plow + rotavatorIrrigation regimes of 60mm irrigation at IW/CPE ratio of 0.6 (I₁), 0.8 (I₂), 1.0 (I₃) and 1.2 (I₄)

	Dry matter	Seed yield	Oil yield	Dry matter	Seed yield	Oil yield
Tillage (T)						
CD (P=0.05)	169	82	32	111	63	27
Irrigation regime (I)						
CD (P=0.05)	132	69	29	98	58	39
T at I						
CD (P=0.05)	272	125	58	171	108	50
I at T						
CD (P=0.05)	212	79	45	142	82	41

drawn wooden plow twice + cultivator twice (T_2), ox-drawn wooden plow twice + power-tiller-drawn rotovator twice (T_3) and tractor-drawn mould plow once + cultivator twice (T_4), respectively, in 1997-98 while the respective percentages in 1998-99 were 84, 45, 24 and 10% (Table 2). Similar effect of the tillage treatments was observed with oil yield of sunflower. These changes were attributed to changes in the amount and distribution of water in the soil profile and to changes in plant rooting patterns. Irrigation at IW/CPE ratio of 1.2 resulted in 5.2, 21.5 and 62% higher yield over IW/CPE of 1.0, 0.8 and 0.6, respectively, in 1997-98 and the respective percentages for 1998-99 were 7.0, 24.2 and 63.1%. Talati and Mehta (1963) reported that grain yield of pearl millet on sandy loam soils of Gujarat, India, was more than double with deep tillage than with shallow tillage. Scheduling 6 cm irrigation at IW/CPE=1.0 also recorded significantly highest yield compared with 0.6 and 0.8, and was at par with the highest soil water regime (IW/CPE=1.2). Interaction effects of tillage and irrigation regimes showed that 180 (1997-98) to 240 mm (1998-99) of irrigation water were saved by providing deep tillage (26 cm) either with disc plow or with mouldboard plow compared with shallow tillage (11 cm) while maintaining yield at optimum levels. The combination of deep-fine tillage and frequent irrigations resulted in significantly high seed yield of 1531 kg/ha (Table 2). This could be attributed to higher plant water status resulting in higher net photosynthetic activity (Upreti and Sirohi, 1985). Although both of the deep tillage treatments (T_4 and T_5) produced large heads and high seed test weight, similar individual plant growth and seed yield, the total seed and oil yield difference was significant because of the significant difference in plant stand. This difference in plant stand was the result of finer tilth achieved with secondary tillage with rotovator.

Water use (WU)

The water use (ETa) of the crop under different tillage practices and irrigations regimes presented in Table 3 indicated that evapotranspiration (ETa) of sunflower under different tillage and irrigation combinations varied from 262 to 495 mm. The average ETa of T_1 , T_2 , T_3 , T_4 and T_5 were found to be 354, 374, 391, 403 and 416 mm, respectively. Increased water use with intensity of tillage contributed to favorable soil physical environment for root penetration, air permeability and higher moisture storage in soil. Better root expansion with deep tillage (T_5 and T_4) increased the capability of plants to extract more water from subsoil (Chaudhury *et al.*, 1985 and Arora *et al.*, 1991) resulting in greater water use. The mean water use in IW/CPE=1.2 moisture regime was highest (471mm) compared with IW/CPE=0.6 (289mm), 0.8 (356mm) and 1.0 (433 mm). Sufficient water availability throughout the crop period under intense irrigation regime enabled the crop to use more water.

Table 3: Effect of tillage treatments and irrigation regimes on water use efficiency ($\text{kg ha}^{-1} \text{ mm}^{-1}$) of sunflower (pooled data of 1998 and 1999)

Tillage (T)	Irrigation regime				
	I ₁	I ₂	I ₃	I ₄	Mean
T ₁	2.05 (262)	2.16 (320)	2.08 (393)	1.97 (439)	2.07 (354)
T ₂	2.45 (278)	2.60 (342)	2.55 (414)	2.45 (460)	2.51 (374)
T ₃	2.62 (290)	2.84 (356)	2.73 (438)	2.69 (478)	2.72 (391)
T ₄	2.89 (303)	3.11 (373)	2.89 (452)	2.80 (483)	2.92 (403)
T ₅	3.14 (313)	3.34 (390)	3.14 (467)	3.11 (495)	3.18 (416)
Mean	2.62 (289)	2.81 (356)	2.68 (433)	2.60 (471)	
(Figures in parenthesis are seasonal crop water use in mm)					
CD (P=0.05)					
Tillage (T)	0.18				
Irrigation regime (I)	0.13				
Interaction					
T at I	0.22				
I at T	0.15				

Water use efficiency (WUE)

Deep-fine tillage obtained in T₅ recorded highest water use efficiency of $3.18 \text{ kg ha}^{-1} \text{ mm}^{-1}$ which was significantly superior to T₁ ($2.07 \text{ kg ha}^{-1} \text{ mm}^{-1}$), T₂ ($2.51 \text{ kg ha}^{-1} \text{ mm}^{-1}$), T₃ ($2.72 \text{ kg ha}^{-1} \text{ mm}^{-1}$) and T₄ ($2.92 \text{ kg ha}^{-1} \text{ mm}^{-1}$). The irrigation regimes at IW/CPE of 0.8 (I₂) resulted in highest WUE ($2.81 \text{ kg ha}^{-1} \text{ mm}^{-1}$). The interaction effect of the tillage practices and irrigations was significant. Deep tillage with tractor-drawn disc plow + rotavator (T₅) in combination of IW/CPE=0.8 was the most efficient with regard to WUE ($3.34 \text{ kg ha}^{-1} \text{ mm}^{-1}$). Under shallow tillage conditions (T₃ and T₂), the WUE did not differ significantly for I₂, I₃ and I₄, however, highest WUE with deep tillage (T₄ and T₅) was recorded with irrigation combination of IW/CPE=0.8. The soil in the deep tillage practices loosened to deeper depths, the improved soil water retention making moisture available to sunflower crop throughout the cropping period. These observations indicate that sunflower responds up to IW/CPE of 1.2 under shallow tillage conditions in rice fallows. Similar observations were also reported by Bhushan *et al.* (1977) for *Brassica compes-tris var. toria* on silty loam soils and Salih *et al.* (1998) for cotton on clayey soils.

Benefit/cost ratio

In general, the tillage practices showed their superiority over zero tillage under rice fallows in benefit/cost ratio (Table 4). Scheduling irrigations at IW/CPE of 1.2 (M₄) resulted in highest B : C ratio of 2.35 in the first year and 2.18 in the second year. Critical examination of net returns and B : C ratio reveals that, under deep tillage conditions (T₅ and T₄), the response to irrigation was up to IW/CPE=1.0, how-

ever, the crop responded up to IW/CPE=1.2 under shallow and zero tillage conditions. The deep and fine tillage (T_5) resulted in highest B : C ratio. At IW/CPE=1.0 and 1.2, T_4 and T_3 tillages did not differ much in the B : C ratio, however, the difference due to these tillage practices (T_4 and T_3) was wide under limited moisture supply (IW/CPE=0.6 and 0.8). It confirms the overall superiority of deep tillage treatments under limited water supply as stated by Vittal (1983).

Table 4: Effect of tillage treatments and irrigation regimes on benefit/cost ratio of post-rainy season sunflower under rice fallows

Treatment	Benefit - cost ratio									
	1997- 98					1998- 99				
	Irrigation regime					Irrigation regime				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
Tillage (T)										
T_1	1.19	1.17	1.18	1.69	1.31	1.06	1.27	1.48	1.56	1.34
T_2	1.48	1.90	2.16	2.23	1.94	1.36	1.68	1.94	2.02	1.75
T_3	1.59	2.04	2.33	2.43	2.10	1.44	1.88	2.15	2.25	1.93
T_4	1.67	2.15	2.32	2.42	2.14	1.58	2.03	2.23	2.25	2.02
T_5	1.82	2.33	2.60	2.65	2.35	1.86	2.13	2.33	2.39	2.18
Mean	1.55	1.92	2.12	2.28		1.46	1.80	2.03	2.10	

CONCLUSION

Deep-fine tilth obtained by one passage of tractor-drawn disc plow + rotavator resulted in significantly higher seedling emergence, crop growth, WUE, seed and oil yield of sunflower. Deep- fine tillage at irrigation regime of IW/CPE=1.0 was the best for sunflower production in rice fallows both in terms of yield and WUE. Deep tillage saved irrigation water to the extent of 18%, in addition to increasing sunflower seed yield by 24%. Partial modification of farmers' tillage practice by substituting secondary tillage of ox-drawn three-tine cultivator with power-tiller-drawn rotavator significantly improved seed and oil yield of sunflower.

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NOTES

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OPTIMIZACIÓN DE LA LABRANZA Y EL RIEGO PARA EL CULTIVO DE GIRASOL EN LOTES DE BARBECHO DE ARROZ (ALFISOLES) DE TRÓPICOS SEMIÁRIDOS

RESUMEN

Se condujeron estudios en un suelo areno arcillo limoso (Haplustalf típico) para evaluar la influencia de cinco prácticas de labranza diferentes y cuatro regímenes de riego (60 mm de riego a $IW/CPE=0.6, 0.8, 1.0$ y 1.2) y su interacción con los cambios físicos del suelo y el comportamiento del cultivo de girasol (*Helianthus annuus* L.) bajo una condición de barbecho de arroz. En términos generales, la labranza tuvo un efecto positivo sobre la emergencia de plántulas, crecimiento y rendimiento de girasol en comparación con la labranza cero en rastrojos de arroz. La labranza profunda primaria con arado de disco o MB tirado por tractor produjo capítulos significativamente más grandes con mayor peso hectolítrico. Sin embargo, la labranza secundaria con rotavator, ya sea autopropulsada o tirada por tractor, realizó un trabajo más fino y se registró una emergencia de plántula significativamente mayor (80.7%). La labranza con arado de discos tirado por tractor + rotavator (labranza profunda y fina) produjo un rendimiento medio significativamente mayor (1311 kg ha^{-1}) sobre el arado MB tirado por tractor + labranza profunda con cultivador tirado por tractor (1172 kg ha^{-1}), arado tirado por bueyes + labranza fina superficial con rotavator autopropulsado (1054 kg ha^{-1}) y arado tirado por bueyes + labranza superficial con cultivador conducido por bueyes (931 kg ha^{-1}). El régimen de riego de $IW/CPE=1.2$ registró un mayor rendimiento en semilla que con $IW/CPE=0.6, 0.8$ y 1.0 . El uso del agua (ETa) por el cultivo de girasol aumentó con el incremento en intensidad de labranza y riego. La eficiencia en el uso del agua fue mayor en prácticas de labranza profunda y con un régimen de riego de $IW/CPE=0.8$. La labranza profunda además permitió ahorrar un 18% del agua de riego resultando en alrededor de un 24% de incremento en el rendimiento de semilla de girasol en comparación con la labranza superficial. Los efectos de interacción revelaron que el crecimiento y rendimiento de girasol significativamente mayores (tanto en semilla como en aceite) se obtuvo cuando la labranza se realizó con arado de disco tirado por tractor + rotavator asociado con esquemas de riego a $IW/CPE=1.0$ o 1.2 . La labranza con dos pasadas de arado + una con rotavator autopropulsado y un esquema de irrigación a $IW/CPE=1.2$ produjo rendimientos de girasol significativamente superiores a las prácticas comunes de los productores.

OPTIMALISATION DE LA CULTURE DU SOL ET DE L'IRRIGATION POUR LA PRODUCTION DU TOURNESOL APRÈS CELLE DU RIZ SUR BRÛLIS EN ALFISOL DANS DES CONDITIONS TROPICALES SEMI-ARIDES

RÉSUMÉ

Des études ont été menées sur sol argilo-sablonneux (Haplustalf) pour évaluer l'influence de cinq conduites avec quatre régimes d'irrigation: irrigation de 60 mm à $W/CPE=0.6, 0.8, 1.0$ and 1.2 , et leur interaction sur les modifications de structure du sol et la performance du tournesol (*Helianthus annuus* L.) dans des conditions de jachère après une culture de riz. Le labour a en général un effet plus favorable que le "zéro labour" sur la levée, la croissance et

le rendement du tournesol. Un premier labour profond avec des disques ou des soc MB a produit des capitules significativement plus grands avec un "test weight" plus élevé; toutefois un labour secondaire avec le rotavator a produit un lit de semences plus fin et a conduit à une levée plus élevée (80.7%). Une façon culturale avec les disques et le rotavator a donné le meilleur rendement (1311 kg ha^{-1}). L'irrigation à $\text{IW/CPE} = 1.2$ a donné de meilleurs résultats que à $\text{IW/CPE} = 0.6, 0.8$ ou 1.0 . L'utilisation de l'eau (ETA) par le tournesol a augmenté avec l'intensité du labour et de l'irrigation. L'efficacité d'utilisation de l'eau [WUE] a été meilleure pour les labours les plus intenses et au régime d'irrigation de $\text{IW/CPE} = 0.8$. Le labour profond, en dehors du fait qu'il entraîne une économie d'eau de 18%, se traduit par une augmentation de 24% du rendement en graines, en comparaison avec un labour peu profond. Les effets d'interaction mettent en évidence que la meilleure croissance et les meilleurs rendements en graines et en huile ont été obtenus lorsque le labour a été fait avec disque et rotavator, associé à un schéma d'irrigation à $\text{IW/CPE} = 1.0$ ou 1.2 . Le labour avec deux passages de socs suivi d'un passage de rotavator pour obtenir un lit de semence plus fin, et un schéma d'irrigation à $\text{IW/CPE} = 1.2$ a donné des résultats significativement supérieurs aux pratiques courantes des agriculteurs.