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RAPPORT ANNUEL SUR L'AMELIORATION DES TECHNIQUES CULTURALES DU RIZ ET SUR LES PROBLEMES RELATIFS A LA SALINITE DE L'EAU ET DU SOL

1961

Dr. C.L. PAN

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1 - PRODUCTIVITE DU RIZ SUR DIFFERENTS TYPES DE SOLS :

Cette année, le riz a été cultivé sur deux types de terrains que nous appelerons :

1) Nouvelles rizières des terrains sur lesquels le riz n'a jamais été cultivé ;

2) Anciennes rizières des terrains ayant porté du riz en 1960.

Des observations en champ ont démontré que les rendements des nouvelles rizières est nettement meilleur que ceux des anciennes. Une analyse statistique a été faite à partir des rendements obtenus sur 23 parcelles dont 12 semées en riz pour la première fois et 11 pour la seconde fois consécutive.

Les résultats de l'analyse de la variance figurent dans le tableau ci-dessous :

1 - Tableau 1 : Analyse de la variance des rendements obtenus sur 2 types de rizières.

Source de variation	Degré de liberté	Moyenne des carrés	F
Traitements	1	6,43	9,7
Parcelles incluses dans les traitements	21	0,66	

La valeur de F montre que la différence de rendement entre les deux types de rizières est hautement significative à 1 % . Le rendement moyen des nouvelles rizières est de 2,51 tonnes/hectare ; celui du second type est de 1,45 tonne/hectare soit une différence entre les deux moyennes de 1,06 T/hectare alors que le plus petit écart significatif a une valeur de 0,68 Tonnes/hectare.

En étudiant ces résultats, on en déduit que les rendements de riz baissent en seconde année de culture sur le même terrain et qu'il faudrait par conséquent éviter de faire riz sur riz. Ceci a été d'ailleurs démontré pour ce qui concerne la culture d'autres céréales tel que le blé.

II - ACCUMULATION DE SEL DANS LE SOL :

De nombreux essais ont démontré que la quantité de sel laissée par les eaux d'irrigation (même chargées) est optimum quand on utilise un fort cubage d'eau et un bon système de drainage. Le supplément d'eau sert dans ce cas au lessivage et à l'élimination des sels par les drains.

Des échantillons de terre ont été prélevés d'un des champs cultivés en tomate, coton, riz, piment et kénaf. En cours de végétation le riz a reçu 4 m3 d'eau contre un seul pour les autres espèces.

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La consommation effective en eau est à peu près égale pour le riz et les autres cultures. Il a été cependant indispensable d'utiliser 4 m3 pour le riz afin de palier à la nécessité de drainage.

Des échantillons de terre ont été prélevés en deux temps : 4 à 5 semaines après la plantation et immédiatement après la récolte. A partir de ces échantillons, on a déterminé la conductivité électrique de l'extrait de pâtes saturée dont les résultats sont les suivants :

Champs	4 semaines après le semis	Après la récolte	Moyenne
Riz:			
Habous Chérif	4,20	3,20	3,70
Habibia	5,42	3,80	4,61
Béjaoua	3,75	4,10	3,92
Moyenne	4,46	3,70	4,08
Tomate			
Béjaoua	5,58	5,45	5,52
Habibia	7,1[illegible]	8,50	7,80
Coton	4,80	4,55	4,68
Piment	9,05	8,50	8,78
Kénaf	6,50	8,00	7,25
Moyenne	6,61	7,00	6,81

La conductivité électrique de l'extrait de pâte saturée est une méthode couramment utilisée pour apprécier la salinité du sol en relation avec des plantes. Une analyse de variance a été calculée à partir des données reportées ci-dessus et les résultats sont consignés dans le tableau .

Tableau 3 : Analyse de la variance des données du tableau 2 :

Mois	1959	1960	1961
Avril	–	2,7	4,0
Mai	2,4	2,1	5,0
Juin	2,9	3,3	4,6
Juillet	–	3,8	4,2
Août	3,3	4,0	5,0
Septembre	2,9	3,4	5,0
Moyenne	2,9	3,[illegible]	4,6

En général les concentrations en sel augmentent en cours de saison et après un maximum en Août elles [illegible] elles furent cependant constantes pendant 1961.

Les données ci-dessus montrent une augmentation progressive de la concentration en sel de l'eau de la Mejerda de 1959 à 1961. La salinité enregistrée en 1961 est doublement plus élevée que celle de 1959.

Les rendements de toutes les cultures ont été fortement affectés par la salinité de l'eau mais à des degrés différents. La différence de tolérance entre les cultures est nettement perceptible si l'on examine le tableau suivant :

.../...

Tableau 5 : Rendement des cultures de 1959 à 1961 (T   )

Cultures	1959	1960	1961
Riz	6,29	5,55	2,51
Coton	2,69	1,45	1,41
Tomate	31,01	12,87	4,71
Kénaf	—	1,56	0,94
Piment Zina	—	8,05	1,13

Malheureusement, il manque les données de 1959 pour le piment et le kénaf, il est donc difficile de comparer les rendements de 1960-1961 avec ceux de 1959.

Il est plus intéressant de convertir les rendements en pourcentage ce qui nous montre alors plus clairement la différence relative durant ces trois années.

Tableau 6 : Rendements relatifs en pourcentage de 1959 à 1961.

Cultures	1959	1960	1961	1961 +
Riz	100 %	88,2	39,9	45,2
Coton	100 %	53,9	52,4	97,2
Tomate	100 %	41,5	15,2	36,6
Piment	-	100,0	-	14,0
Kénaf	-	100,0	-	60,2
Moyenne ++	100 %	61,1	35,8	

\+ En comparaison avec les rendements de 1960 convertis en 100 %

++ Moyennes de rendement des trois premières cultures.

Les rendements en riz pour 1960 étaient de 88,2 % par rapport à 1959 ... : 53,9 % pour le coton et de 41,5 % pour la Tomate. Comme les conditions dans lesquelles ces trois cultures ont été menées au cours de ces deux années ont été les mêmes, excepté pour la salinité de l'eau, on peut conclure que les différences de rendement entre les cultures sont uniquement dûes à l'augmentation de la concentration en sel de l'eau d'irrigation.

En outre, quand la concentration en sel passe de 3,2 Millimhos en 1960 à 4,6 Millimhos en 1961, les rendement changent en conséquence. Les chiffres donnés dans la dernière colonne du tableau 6 représentent? Les rendements culturaux de 1961 en pourcentage par rapport à ceux obtenus en 1960.

Ces données démontrent clairement que le coton a une chute de rendement moins forte, la Tomate et le Piment plus accentuée et que par contre les rendements du riz et du Kénaf se situent entre les deux extrêmes.

Il est intéressant de noter ... les différences entre les rendements moyens du riz, du coton, et de la Tomate durant les trois dernières années. On peut remarquer dans le tableau 6, qu'avec les rendements de 1959 pris comme 100 %, le rendement des cultures est de 61,2 % en 1960 et de 35,8 % en 1961. Cette baisse dans les rendements montre que lorsque la concentration en sel de l'eau d'irrigation est de 4,6 Millimhos, les rendements peuvent être remarquablement affectés. Il semble raisonnable d'affirmer que les eaux dont la salinité est supérieure à 4,5 Millimhos, ne sont pas d'une grande valeur pour l'irrigation.

Il est vraisemblable que la concentration en sel des eaux de la Mejrada sont en relation étroite avec la pluviométrie. Quand celle-ci est élevée sur les versants réservoir, l'eau devient en effet plus douce. Malheureusement, les relevés des chutes de pluie dans la Vallée et spécialement en Algérie ne sont pas disponibles. Néanmoins pour la région de TUNIS, ces données sont disponibles depuis 1875. On les emploiera dans cette étude en pensant que la Vallée de la Mejrada ait reçu les mêmes précipitations.

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Bien que les relevés de la salinité de l'eau n'ont eu lieu que sur les trois dernières années, une relation certaine apparait entre les précipitations et la salinité comme le démontre le tableau 7 :

Années	Pluies annuelles de Sept à Août en mm	Conductivité électrique moyenne d'Avril à Sept. en Millimhos
1959	807,8	2.9
1960	393,4	3,2
1961	194,0	4,6

Avec des données sur la salinité s'etendant sur trois années seulement, il n'est pas possible d'estimer le coefficient de régression mais la relation entre les deux facteurs est évidente. La faible salinité de l'année 1959 est evidemment dûe aux chutes de pluie importante et vis versa quant à l'année 1961.

Comme nous l'avons mentionné plus haut, une salinité de 4,6 Millmhos est peut être la limite extrême de tolérance pour la plupart des cultures. A partir des données présentées ci-dessus, la salinité de l'eau atteindrait ce niveau quand la pluviométrie annuelle est de l'ordre de 200 m/m

Un fait notable réside dans le fait que sur les 86 dernières années (de 1875 à 1961) la très faible pluviométrie enregistrée en 1961 a été exceptionnelle. La tableau 8 nous présente la distribution de fréquence de la pluviométrie durant les 86 années.

<u>Tableau 8</u> : Fréquence de distribution de la pluviométrie de 1875 à 1961

Classe de pluviosité:	Fréquence de distribution
101-200	1
201-300	9
301-400	24
401-500	25
501-600	16
601-700	9
701-800	1
801-900	1
TOTAL :	86

Il y a une année sur 86 dont la pluviométrie est inférieure à 200 m/m (1961) où l'enregistre une forte salinité de l'eau d'irrigation et parsuite une baisse sensible dans les rendements. Le tableau 8 nous indique d'autre part qu'il y eu 76/86 années (1875-1961) où la pluviométrie a été supérieure à 300 m/m comme en 1961 pendant les quelles les rendements culturaux ont été satisfaisants. C

Cependant 1/86 années qui se caractérisepar une forte pluviométrie allant jusqu'à 800 m/m -(1959).

S'il existe une relation entre la pluviométrie et la salinité de l'eau de la Mojrada et s'il y en a une autre entre la salinité de l'eau et les rendements il est possible de conclure que 8/9 années les cultures irriguées croissent normalement dans le périmètre et qu'une année sur neuf les récoltes peuvent être soit très mauvaises (1961) soit très bonnes (1959).

.../...

IV - DRAINAGE :

Le drainage est d'autant plus important que l'eau d'irrigation est chargée en sel. Des résultats expérimentaux ont démontré qu'avec un bon système de drainage, les dépôts de sel dans le sol peuvent être diminués et par suite engendrer un meilleur rendement.

De nombreux essais de drainage ont été menés durant 1960-1961 en vue de déterminer le drainage optimum à adopter sur les rizières. Le drainage optimum n'est pas calculé sur la base de rendement uniquement mais aussi sur la consommation en eau et sur le coût de confection de drains.

Un grand nombre de drains entraine une forte consommation d'eau L'aménagement des fossés de drainage est onéreux, il est estimé à 150 Millimes le mètre linéaire pour une profondeur et une largeur de 75 cm.

Cet essai consistait à comparer trois dispositifs de drainage dont l'écartement des drains est différent à savoir :

- A - 15 mètres
- B - 25 mètres
- C - 35 mètres

et dont la profondeur et la largeur des drains sont identiques.

L'essai a été conduit durant deux années consécutives et à trois endroits à la fois dont le % de saturation est de 50 %. La variété utilisée était Ballila.

Les résultats obtenus ont été soumis à l'analyse de la variance qui a abouti à la conclusion suivante : pour les deux années et les trois traitements il n'y a pas de différence significative comme le démontre le tableau 9.

Tableau 9 :

Distances entre canaux	1960	1961	Moyenne
15 mètres	5,10	1,53	3,32
25 mètres	5,60	2,30	3,95
35 mètres	5,05	1,92	3,48

Bien que la différence entre les trois traitements ne soit pas significative, le rendement moyen des parcelles de 25 mètres d'écartement entre les drains, a été le plus élevé pendant les deux années. Un écartement de 15 m assure un drainage excessif et parsuite une perte considérable d'eau dont les conséquences peuvent provoquer une diminution dans les rendements.

En considération l'onérosité de la confection de drains et l'importance d'économiser l'eau d'irrigation, il serait utile de conseiller d'adopter un écartement de 35 mètres entre les drains pour un terrain de 50 % de saturation.

V - VARIETES :

La culture du riz étant impratiqué en Tunisie, il a fallu importer, en 1959, 127 variétés de 8 pays différents en vue de test et de retenir les plus prometteuses sous le climat de la Mejrada. La variété Ballila a été prise comme témoin et insérée à tous les 10 lignes.

Durant le cycle végétatif des annotations ont été faites sur le comportement relatif des variétés à l'essai. 17 variétés seulement ont été retenues pour un examen plus approfondi.

Ces 17 variétés ont été reprises de nouveau en cours de 1960 et 1961 et seules 6 ont survécu à la forte salinité des eaux d'irrigation de 1961. Ces dernières peuvent être considérées comme effectivement tolérantes au sel.

La variété Balilla se favorise par un bon tallage, des graines denses et d'un haut pourcentage de panicules et d'une résistance satisfaisante au sel. Cependant les graines sont courtes, petites et deviennent pâteuses et gluantes après cuisson ; ce qui la déprécie au point de vue commercial. Une amélioration est possible en procédant à son croisement avec une variété à graines longues.

VI - ENGRAIS :

En général, le riz ne répond pas aux apports d'engrais phosphatés et potassiques mais réagit favorablement à l'azote comme toutes les autres céréales.

Des essais d'engrais ont été réalisés au cours des trois dernières années dont le but est de préciser l'action de chaque élément fertilisant (NPK) sur les rendements du riz. Quatre traitements ont été choisis à savoir

- 1 - Azote seule
- 2 - Azote + Phosphate
- 3 - Azote + Potasse
- 4 - Azote + Phosphate + Potasse.

Les engrais ont été épandus en cours de préparation du sol à la dose de 60 kgs/ha de chaque élément et sous la forme de sulfate d'ammoniaque, de superphosphate et de sulfate de potasse.

Cette année les traitements sont répétés 4 fois et disposés en carrés latins 4 x 4.

L'analyse statistique des résultats obtenus nous révèle que durant les 3 ans les apports d'engrais phosphatés et potassiques n'ont pas augmenté les rendements du riz.

Tableau 10 : Réaction du riz aux apports d'engrais (Rendements en T/ha)

traitements	1959	1960	1961	Moyenne
N	10.62	5,80	2,09	6,17
NK	9,95	7,34	1,88	6,39
NP	9,92	6,60	2,71	6,41
NPK	9:13	6,82	2,61	6,19

Les rendements moyens pour les 4 traitements et pour les 3 années se situent entre 6,0 et 6,50 tonnes/hectare. Il n'y a pas de grands écarts entre les moyennes ce qui veut dire que l'effet des engrais phosphatés et potassiques n'est pas remarquables dans les rendements du riz. Quant à l'action d'Azote, il est difficile de la ressortir à partir des résultats obtenus puisque les 4 traitements en contiennent. De ce fait un essai supplémentaire a été conduit en 1961 en utilisant différentes doses d'engrais azotés et un témoin sans azote. Malheureusement, la forte salinité de l'eau d'irrigation a entravé la croissance du riz et par suite il nous a été impossible de relever des données notables.

VII - AUTRES ETUDES :

En 1959 et en 1960, des essais de densité et de dates de semis ainsi que des essais sur l'application de soufre et de gypse ont été effectués. Ces essais ont donné les résultats concluants sauf en 1961.

Il n'y a presque pas de différence entre les rendements obtenus de 120 kgs de 160 kgs de semences par hectare. Il semble cependant préférable d'employer 180 kgs afin de palier des pertes à la germination dues à la forte salinité des sols.

Les résultats obtenus nous précisent la période opportune de semis qui est située entre le 20 Avril et 15 Mai. Au delà de cette période la germination du riz peut être entravée soit par une insuffisance de température, soit par un taux élevé en sel des eaux d'irrigation.

L'apport de soufre ou de gypse dans les rizières n'est pas recommandable. Il semble en effet que le carbonate de soude laissé dans le sol par les eaux d'irrigation et sous une forme assez soluble pour son lessivage Les sels insolubles sont en effet les plus dangereux pour la croissance des végétaux car ils ne peuvent être éliminés par les eaux d'irrigation.

D'autre part, l'application de soufre et de gypse a diminué les rendements, cela est probablement dû à une certaine méconnaissance de l'effet toxique que ces deux produits ont sur la germination des graines.

VIII - IRRIGATION PAR POMPAGE :

Le débit de la Mejrada (à l'aval du barrage d'El Arousia) est estimé de 1 à 3 m3 par seconde dont une partie est employée par des agriculteurs riverains, l'autre s'écoule vers la mer. Aussi leur utilisation par pompage présenterait un grand intérêt et pourrait favoriser l'introduction de la culture du riz. L'établissement d'un système de drainage est réduit à quelques fossés exécutés au tracteur ; la présence de l'Oued Mejrada facilite en effet l'évacuation des eaux.

A cette fin, un champ de 3 hectares situé sur la rive gauche de la Mejrada, à Kantart Bizerte, a été semé en riz en 1961. Il était irrigué directement de l'Oued à l'aide d'une petite pompe. Le coût s'élevait à 1,2 Millime environ par mètre cube.

Toute la préparation du terrain, comprenant un labour, un drainage un nivellement et la confection de diguettes a été faite au tracteur. Comme la potasse et le phosphate n'ont pas d'influence sur les rendements du riz on a employé du sulfate d'ammoniaque à raison de 300 kgs/ha.

Malheureusement le riz n'a pas bien poussé dans ce champ donnant 1,042 tonne de paddy soit 300 kgs/ha. Ce rendement est très bas en le comparant aux rendements obtenus la même année à Béjaoua.

Ce faible rendement semble être dû à la haute teneur en sel de l'eau d'irrigation et à l'insuffisance du système de drainage dont le principal élément est l'oued de la Mejrada.

Des échantillons d'eau ont été prélevés 2 fois par semaine pendant la saison culturale, simultanément à Kantart Bizerte et au Canal d'irrigation de Béjaoua. La conductivité électrique a été déterminée.

Tableau 11 : Concentration en sel de l'eau à Kantart Bizerte et à Béjaoua :

Mois	Béjaoua (Millimhos)	Kantart Bizerte
Mai	5,06	5.67
Juin	4.44	4.97
Juillet	4.21	4.23
Août	4.90	5.31
Septembre	4.59	5.25
Moyenne	4.64	5.09

La concentration en sel de l'eau était de 5,09 Millimhos à Kantart Bizerte contre 4,64 à Béjaoua. La station de pompage desservant Béjaoua est alimenté par le barrage d'El Aroussia, l'eau prise à ce niveau renferme en effet moins de sel que celle pompé directement de la Mejrada à laquelle débouchent tous les réseaux de drainage.

Bien que la différence de conductivité électrique entre les 2 points soit égale à 0,9 %, les rendements ont baissé de 2,5 à 0,3 Tonnes hectare. Cela veut dire que les rendements en riz ne sont pas proportionnel à la salinité des eaux d'irrigation mais cumulatifs.

On a également constaté que le drainage n'était pas suffisant dans ce champ. Ce-ci est mis en évidence par le fait que l'on a utilisé 25.000 m3 d'eau par hectare contre 45.000 m3 à Béjaoua où il existe un bon système de drainage. Comme conséquence de l'insuffisance de drainage et de la hautre concentration en sel de l'eau d'irrigation, les dépôts de sel dans cette parcelle ont été plus élevés que dans les rizières de Béjaoua.

Tableau 12 : Dépôts de sel dans les rizières de Béjaoua et de Kantart Bizerte.

Lieux	Echantillons de sel pris 4 semaines après le semis	E. de sel pris après la récolte	Moyenne
Béjaoua	3,75	4,10	3,92
Kantart Bizerte	7,10	7,50	7,30

La salinité moyenne du sol à Kantart Bizerte s'élève à 7,30 Millimhos contre 3,92 à Béjaoua. Cette élévation est du principalement à la défectuosité du système de drainage et a engendré une baisse remarquable des rendements. Il semble ressortir de ces résultats qu'une salinité supérieure à 4 Millimhos est néfaste à la culture de riz.

IX - ETUDE DU COUT DE PRODUCTION :

En 1961, le riz a été cultivé dans deux régions et suivant deux systèmes d'irrigation différents à savoir :

- À El Habibia, Béjaoua et Mcazzia totalisant 19,4 hectares et irrigués par gravité ;

- À Kantart Bizerte où 3 hectares ont été irrigués par pompage direct dans l'oued de la Mejrada

Le coût de production a été fait à partir de relevés soigneusement pris sur toutes les opérations culturales et il s'élève à :

Tableau 13 : Coût de production du riz en 1961 :

Travaux	Kantart Bizerte par Pompage		Autres régions par gravité	
	Coût total 3 ha	Coût / ha	Coût total 19,40 ha	Coût / ha
Labour	13.000	4.333	56.000	2.886
Disquage	6.000	2.000	53.000	2.732
Nivellement	24.250	8.083	14.500	0.747
Fumure	21.600	7.200	417.337	21.507
Semences	17.500	5.850	141.120	7.276
Main d'oeuvre	70.700	23.567	1.609.450	82.961
Récolte	27.000	9.000	387.950	19.997
S/ Total	180.050	60.033	2.679.257	138.106
Irrigation	89.760	29.920	1.767.506	91.108
Total	269.810	89.953	4.446.763	229.214

Labours, diguage et nivellement	
Fumier	0,500/heure +
Sulfate d'ammoniaque	1,400 la tonne
Superphosphate 16	2,400 le quintal
Sulfate de potasse	1,190 le quintal
Semences de riz	3,600 le quintal
Salaire journalier main d'oeuvre	4,500 le quintal
(semis, désherbage, épandage d'engrais etc..	0,350
Moisson Battage	2,500 l'heure
Prix d'un mètre cube d'eau	
- par pompage direct dans la Mejrada	0,0012
- " irrigation par gravité	0,002

Le prix de revient cultural s'élève à 89,953 Dinars/hectare sur les rizières irriguées par pompage direct dont 23,567 pour la main d'oeuvre et 29.920 dinars pour l'eau d'irrigation. Alors qu'il est de 229,255 Dinars dans les autres rizières dont 82,961 Dinars pour la main d'oeuvre et 91,108 D. pour l'eau d'irrigation. La différence est attribuée au fait que la rizière de Kantart Bizerte était destinée à la production uniquement et où moins d'eau a été utilisé par suite d'une insuffisance de drainage.

Dans ces conditions on peut conclure que le riz irrigué par pompage doit produire un peu plus de 2 tonnes par hectare pour couvrir les frais culturaux. Quant au riz irrigué par gravité il en faudrait 3,8 tonnes hectare.

Quand la pluviométrie est normale comme celle de l'année 1960 la concentration en sel se situe aux environs de 3,2 Millimhos et de rendement en riz est de 5,5 tonnes/hectare. Si l'on admet une augmentation de la salinité de 10 % à Kantart Bizerte en 1960, nous aurions une conductivité électrique de 3,6 millimhos. A ce niveau le rendement en riz serait supérieur à 2 tonnes par hectare, ce qui semble être rentable.

En année normale au point de vue pluviométrie, la salinité de l'eau d'irrigation peut être assez basse et permettre ainsi de cultiver avantageusement le riz soit par pompage direct dans la Mejrada, soit par gravité. Cependant, cette conclusion basée sur des données issues de 3 ans, doit être confirmée par des études supplémentaires.

X - CONCLUSION :

Les faibles rendements en riz enregistrés en 1961 où la pluviométrie a été inférieure à la moyenne et où la salinité de l'eau était à son maximum, nous incitent de s'attaquer aux problèmes très importants concernant les relations entre la salinité et la pluviométrie et entre la salinité de l'eau et les rendements culturaux.

Bien que le riz ne s'est pas révélé l'espèce la plus tolérante au sel, il y a lieu de le classer parmi les plus résistantes. Or en années normales la culture du riz est réellement rentable.

Après trois années d'étude et d'essai, une technique culturale appropriée au périmètre de la Mejrada a été mise au point et d'autre part des problèmes nouveaux autre que l'introduction du riz, se sont soulevés et nécessitent d'être résolus afin d'améliorer la production rizicole.

Tous les essais et travaux relatés dans le présent rapport ont été réalisés par l'Office de la Mise en Valeur de la Vallée de la Mejrada avec l'assistance technique de la F.A.O. à laquelle nous adressons de nouveau toute notre gratitude ./.

CNOA 34057

Annual Report on Rice Improvement and its related
Problem of Water and Soil Salinity
for 1961

TAN, C.L.

This is the third year in experimenting with rice growing in the Medjerda Valley. Many field trials were conducted in this year, and the results obtained are briefly presented as under.

I. Rice productivity on different types of land

In this year rice was grown on two types of land, namely, 1) land A on which no rice has been grown before, and 2) land B on which rice was grown in the last year. Field observation had revealed that rice grown on land A was obviously better than that on land B, and, therefore, a statistical analysis was made on the yields obtained from 23 parcels, of which 12 parcels were of land A and 11 were of land B.

The results from the analysis of variance are given below:

Table 1. Analysis of variance of the yield data obtained from the two types of land

Sources of variation	Degrees of freedom	Mean square	F
Treatments	1	6.43	9.6
Within treatments	21	0.66	

The F value as given in the above table has shown that the two types of land gave yields significantly different from each other at the 1 percent level. The yield of land A averaged at 2.51 tons per hectare and that of land B at only 1.45 tons with a difference of 1.06 tons, which was larger than the calculated L.S.D value of 0.68 ton per hectare.

From this study it became obvious that rice yield on land A was superior to that on land B. In other words, rice should not be grown continuously on the same land for more than one year. A proper system of rotation must be followed.

II. Salt accumulation in the soil

When the irrigation water contains salts, the land to be irrigated with such water would easily become salinized if no proper drainage is provided. The salt brought into the land through the irrigation water will be deposited in the soil unless it is washed off through drainage water.

We have found in many experiments that salt deposit in the soil seems to be less when more salt water is used in irrigating the land. But this is true only when the excess water is drained away. Numerous field trials have demonstrated the effectiveness of leaching for salt removal. With good drainage the efficiency of leaching is increased by using more irrigation water even when such irrigation water contains some salt. Under such condition salt brought into the land by the irrigation water would be left behind in the soil at a much lower rate.

Soil samples were taken from many fields planted to various crops of rice, tomato, cotton, pepper and kenaf. During the course of the season

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the rice fields were irrigated with about 4 meters of water, while the fields for the other crops were irrigated with only about one meter. Since the consumptive use of water for rice is about the same as for other crops, the quantity of water lost through drainage should be, therefore, much more in a rice field than in a tomato or cotton field. This increase in the rate of drainage should result in less salt deposit in the soil.

Soil samples were taken twice, one at the time about 4 or 5 weeks after planting, and the other at the time soon after the harvesting of the crops. These soil samples were made into saturation pastes, and the electrical conductivity of the water extracted from these saturation pastes was measured. The results are given below:

Table 2. The electrical conductivity of the soil samples taken from various fields at two different times

Fields	4 weeks after sowing	Soon after harvesting	Average
	in millimhos		
Rice fields:			
Baloum Cherif	4.20	3.20	3.70
Habibia	5.42	3.80	4.61
Bajaoua	3.75	4.10	3.92
Average	4.46	3.70	4.08
Tomato fields:			
Bagaoua	5.98	5.45	5.52
Habibia	7.10	8.50	7.80
Cotton field	4.80	4.55	4.68
Pepper field	9.05	6.50	8.78
Henof field	6.50	8.00	7.25
Average	6.61	7.00	6.31

The electrical conductivity of the saturation extract has been widely used as a general method for appraising soil salinity in relation to plant growth. An analysis of variance for the above data was made and the results obtained are given below:

Table 3. Analysis of variance for the data as presented in Table 2

Sources of variation	D/F	Sum of squares	Mean square	F
Treatments:	3	29.0852		
Fields rice vs non-rice	1	27.6393	27.84	12.6
Samples at 4 weeks vs after harvesting	1	0.0056		
Interaction	1	1.2403		
Error	12	26.3620	2.20	
Total	15	55.4472		

The electrical conductivity of the saturation paste in the rice fields averaged at 4.08 millimhos as compared with 6.81 millimhos in the other fields; and their difference was found to be statistically significant as indicated

.../...

by large F value of 12.6. The data have also revealed that, although the interaction was not significant statistically, the salinity of the rice fields was found to be reduced from 4.46 millimhos during the time at 4 weeks after sowing to only 3.70 millimhos at the end of the experiment, whereas the soil salinity of the other fields was increased from 6.61 millimhos to 7.00 millimhos during the same period.

It is obvious that salt deposit in the rice field was less than that in the other fields. This is evidently due to the fact that in the former more irrigation water had been used, thus providing more excess water for drainage.

The average saturation percentage of all the soil samples taken at the second time was found to be 51.4%. With such saturation percentage, the electrical conductivity of the saturation paste extract of 4.1 millimhos as found in the rice fields would be approximately equivalent to 0.12 percent of salt in the soil, and that of 6.8 millimhos as found in the other fields to about 0.22%. It has been reported that crops of similar salt tolerance can grow relatively well on soil with only 0.1% of salt whereas crop yields on soil with more than 0.2% would be greatly deteriorated.

III. Relative salt tolerance of rice and other crops

Many experimental results have demonstrated that crop plants differ in salt tolerance. As the Medjerda water contains salt, the continuous use of such water for irrigation would pose a problem of salt deposit in the soil. It is, therefore, important to study the relative salt tolerance of different crops in the hope that only crops with greater tolerance are to be grown in the Valley.

Five irrigated crops of rice, cotton, kenaf, tomato and pepper have been grown in the Medjerda Valley during the last 3 years under very similar conditions except for the irrigation water, which was found to be of great difference in their salt content.

Water samples were taken almost daily at the pumping station at Sidi Thabet since May 1959 by the Pedology Service, and their electrical conductivities were measured. For the sake of brevity only the monthly average for April through September was computed, as only the salt concentration of the water during these months would have effect on the development of the five crops which are all grown during late March through early October. The salinity data of the water are given below:

Table 4. Average electrical conductivity of the Medjerda water during 1959 to 1961

Months	1959	1960	1961
	millimhos		
April	—	2.7	4.0
May	2.4	2.1	5.0
June	2.9	3.3	4.6
July	—	3.8	4.2
August	3.3	4.0	5.0
September	2.9	3.4	5.0
Average	2.9	3.2	4.6

.../..

In general the salt concentrations increased as the season advanced; and after reaching its peak in August, it then receded. But in 1961 it was constant throughout the year.

The data/given above have shown a progressive increase in the salt concentration of the Medjerda water from 1959 to 1961, and in 1961 it was almost twice as high as that in 1959.

It was found that the water salinity has greatly affected the yields of all crops, but with different degrees. This difference of tolerance between crops is clearly shown by the data as given in the following table.

Table 5. Crop yields in 1959 - 1961 (tons/hectare)

Crops	1959	1960	1961
Rice	6.29	5.55	2.51
Cotton	2.69	1.45	1.41
Tomato	31.01	12.87	4.71
Kenaf	—	1.56	0.94
Pepper Zina	—	8.05	1.13

Unfortunately yield data for kenaf and pepper in 1959 were not available, and therefore it is not possible to compare its yield of 1961 and 1960 with that of 1959.

It is more interesting to convert the yield data as given in the above table into percentage, which would then show more clearly the relative difference in yield during these 3 years.

Table 6. Relative yield in percentage during 1959 - 1961

Crops	1959	1960	1961	1961*
Rice	100%	88.2	39.9	45.2
Cotton	100%	53.9	52.4	97.2
Tomato	100%	41.5	15.2	36.6
Pepper	—	100.0	—	14.0
Kenaf	—	100.0	—	60.2
Average**	100.0	61.2	35.8	

* In comparision with 1960 yield as 100%

** Average of the first 3 crops only (not including kenaf and pepper Zina)

Rice yield in 1960 which was 88.2% of the 1959 yield, was most satisfactory in comparison with the yield of cotton and of tomato, which in the same year yielded only 53.9% and 41.5% respectively. Since all the conditions under which these 3 crops were grown in these two years were identical except for the difference in the water salinity, the reduction in yield in 1960 must have been caused by the increase of salt concentration in the Medjerda water.

However, when the salt concentration further rose from 3.2 millimhos in 1960 to 4.6 millimhos in 1961, the yield pattern of the crops changed. The figures given in the last column of the above table represents the crop yields of 1961 in percentage of those of 1960.

The data have clearly shown that cotton gave the highest yield, and tomato and pepper the lowest, whereas the yield of kenaf and rice lay in between them. This indicates the salt tolerance of these 5 crops in that order.

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It is interesting to note the difference in the average yield of rice cotton and tomato during the last 3 years as given at the bottom of the above table. It is seen that with the yield of 1959 as 100% the average yield of the three crops was 61.[illegible]% in 1960 and 35.8% in 1961. This shows that when the salt concentration of the irrigation water rose to 4.6 millimhos, crop yields would be severely affected. It seems appropriate to say that waters with salinity of over 4.5 millimhos would be of no great value to be used for irrigation.

It is believed that the salt concentration of the water may have some relation with rainfall, as it seems obvious that more rain falls in the region where the river flows,more dilute its water becomes. Unfortunately, rain record in the valley,especially in the Algerian territory where the Medjerda River actually originates,is not available. However, such record is available in Tunis back to 1875, which is used in the present study in the belief that since the Medjerda region is not too large after all, rainfall in Tunis may be similar to that in the whole region.

Although our data on the salinity of the water is limited to a period of only three years, there appears to have a close relation between rainfall and water salinity. The data are given below;

Table 7. Relation between rainfall and water salinity

Year	Yearly rainfall from Sept. to August (in mm)	Average electrical conductivity from April to September (in millimhos)
1959	807.8	2.9
1960	393.4	3.2
1961	194.0	4.6

With salinity data only for three years, it is not possible to estimate the coefficienet of regression, but nevertheless the relationship between these two factors is obvious. The low salinity in 1959 was evidently due to the high rainfall, and, likewise, the low rainfall in 1961 has resulted in the high salinity of the water.

As previously stated water salinity of 4.6 millimhos may be the maximum limit for most of the crops to tolerate , and from the data as given above the salinity of the water would rise to this level when the annual rainfall declines to less than 200 mm. This statement, however, is made only according to the relationship as established by the 3-year data as presented in the above table.

A review of the rain record during the last 86 years from 1875 to 1961 has revealed a very encouraging fact that the drought in 1961 was a very rare occurrence indeed. The following table presents the data on the frequency distribution of the yearly rainfall during the last 86 years.

Table 8. Frequency distribution of the yearly rainfall from 1875 to 1961

Rainfall range	Frequency distribution
101 - 200	1
201 - 300	9
301 - 400	23
401 - 500	25
501 - 600	16
601 - 700	7
701 - 800	1
801 - 900	1
	86

A test was made by using the second, third, and fourth powers to determine whether the above rainfall distribution is of the normal form. From this test we found the following values:

$$g_1 = -0.26 \pm 0.10$$

$$g_2 = 2.82 \pm 0.51$$

Both g_1 and g_2 were significant as they were greater than their standard error by more than two times, but g_1 was negative and smaller than 1, whereas g_2 was positive and much larger. A small negative but significant g_1 value means that the curve of the actual rainfall distribution was slightly skewed or asymmetrical, and a relatively large and significant positive g_2 value means that the curve is obviously peaked. This test of normality of the distribution curve has revealed one very interesting fact that during the last 86 years moderately wet and very wet years are respectively more frequent than moderately dry and very dry years. During that period there was only one year that had an annual rainfall of less than 200 mm; and that year was 1961 during which crop production was only 38.5% of that in 1959, which was also the only year having an annual rainfall of over 800 mm. However, the rainfall of 393.4 mm in 1960 was rather normal. Among the last 86 years there were 53 years having an annual rainfall of more than 400 mm. Crop yields in 1960, although only 61% of that in 1959, should be considered very satisfactory. For instance, rice yield in that year averaged at 5.55 tons per hectare, nearly equal to the world's highest yield as obtained in Spain and Egypt.

If the data as shown in the above table represent the true relationship between the salinity of the water and the rainfall in Tunis, and between the salinity of the water and the crop yields, then we can say that crop yields in the Medjerda Valley could be expected to be very satisfactory in most of the years; and only in one year out of 86 years crop yields may be affected by the lack of rainfall, which in turn would increase the salt concentration of the Medjerda water beyond the level that most crops can tolerate. In years with plenty of rain in the spring more acreage should be planted to tomato and pepper, which, under favorable conditions, seem always to give a much higher profit, but in years with less rain, more cotton or rice should be grown as they are more tolerant to salt.

IV. Drainage

Drainage is important especially when the irrigation water contains salt. Experimental results have shown that with good drainage salt deposit in the soil would be curtailed, which in turn would increase crop yields.

Many drainage experiments have been conducted during the last 2 years in order to determine the optimum drainage for a rice field. Optimum drainage is determined not only on the basis of rice yields, but also on the basis of water consumption and the cost of digging the ditches. More draining ditches often mean to need more irrigation water. And the cost of digging the ditches would be very expensive estimated at about 150 millimes per meter of ditch of 75 cm deep and 75 cm wide.

This trial consisted of 3 parcels provided with draining ditches of about 75 cm deep and wide at 3 different distances between the ditches, namely, (1) 15 meters, (2) 25 meters, and (3) 35 meters, and was conducted during the last 2 years in three places in the Medjerda Valley. Each treatment was repeated twice in each place, and the seeds of the variety Balilla were used in both years.

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Drainage is important especially when the irrigation water contains salt. Experimental results have shown that with good drainage salt deposit in the soil would be curtailed, which in turn would increase crop yields.

Many drainage experiments have been conducted during the last 2 years in order to determine the optimum drainage for a rice field. Optimum drainage is determined not only on the basis of rice yields, but also on the basis of water consumption and the cost of digging the ditches. More draining ditches often mean to need more irrigation water. And the cost of digging the ditches would be very expensive estimated at about 150 millimes per meter of ditch of 75 cm deep and 75 cm wide.

This trial consisted of 3 parcels provided with drainage ditches of about 75 cm deep and wide at 3 different distances between two ditches, namely, (1) 15 meters, (2) 25 meters, and (3) 35 meters, and was conducted during the last 2 years in three places in the Medjerda Valley. Each treatment was repeated twice in each place, and the seeds of the variety Belilla were used in both years.

Yield data obtained from this trial were subjected to an analysis of variance, and in both years it was found that the 3 treatments were not significantly different from each other. The yield data are given below:

Table 9. Average yield of the drainage trial

Distances between 2 ditches	1960	1961	Average
15 meters	5.10	1.53	3.32
25 "	5.60	2.30	3.95
35 "	5.05	1.92	3.48

Although not significantly different between the 3 treatments, the average yield of the 25-meter plot yielded somewhat higher in both years. When the plot was provided with ditches of 15 meters apart, the rice had to suffer occasional drought due to too good drainage, which thus made water very difficult to be kept in the plot all the time. This occasional drought might have lowered the yield of the rice.

In view of the high cost of digging the ditches and of the importance of economizing the use of the irrigation water, it seems appropriate to suggest that rice growing in the Medjerda Valley would only need drainage ditches of 75 cm deep and 75 cm wide at a distance of at least 35 meters apart.

V. Varieties

As rice is a new crop in Tunisia, there is no existing variety to be used for breeding. In 1959 127 varieties were introduced from 8 countries, and in the same year each variety was planted to a short row with every 10th row planted to the variety Balilla as the check, which was introduced before 1959.

During the course of the season several field observations were made to record the general growth of the different varieties with particular attention to comparing it with that of the check variety. At the end of the season, however, only 17 varieties were selected for further testing.

These 17 varieties were again tested in 1960 and 1961, but due to the increased salt concentration of the Medjerda water in 1961 many of them were perished, leaving only 6 varieties finally survived at the end of the season. They were therefore considered to be most tolerant to salt. Balilla, being one of the six, has many other desirable characters, which include (1) good tillering, (2) high percentage of ear-bearing tillers, and (3) heavy seeds, all of which are important components to determine the yield of rice. Therefore, in spite of its being grown on land with high percentage of salt, Balilla still gave satisfactory yields. Unfortunately, its seed is very small and short, and becomes very sticky and gluey after cooking, which, however, could be improved by launching a program of cross-breeding with such long-grained variety as Stirpe 136.

VI. Fertilizers

In many places rice usually does not respond to phosphorus and potash, but needs nitrogen just like many other cereal crops. A trial was conducted in the last 3 years to determine the effect of these fertilizers on the yield of rice. It consists of 4 treatments, namely, (1) nitrogen alone, (2) nitrogen and phosphorus, (3) nitrogen and potash, and (4) nitrogen, phosphorus and potash. The fertilizers were applied at the rate of 60 kgs per hectare for each of the 3 elements with ammonium sulphate for nitrogen, superphosphate for P_2O_5 and potassium sulphate for K_2O.

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In each year the 4 treatments were replicated 4 times arranged in the form of a 4 x 4 latin square. Experimental results were analyzed statistically.

As indicated by the F values, the 4 treatments were not significantly different in all the 3 years, showing that the addition of potash and phosphorus did not increase the rice yield. The data are given below:

Table 10. The response of rice in terms of its yield to fertilizers

Treatments	1959	1960	1961	Average
N	10.62	5.80	2.09	6.17
NK	9.95	7.34	1.88	6.39
NP	9.92	6.60	2.71	6.41
NPK	9.13	6.82	2.61	6.19

The average yield of the 3 years for the 4 treatments was all within the range of 6.0 to 6.5 tons per hectare without much difference, indicating that the application of potash or phosphorus or both did not improve the rice yield. However, the results of this trial did not reveal the effect of nitrogen as in all the 4 treatments contained nitrogen. Therefore an additional trial to study this nitrogen effect was conducted in 1961, but unfortunately due to the high salinity of the irrigation water this trial failed to produce a satisfactory result.

VII. Other studies

During 1959 and 1960 trials on rate and date of seeding and the application of gypsum and sulfur were conducted. As all these trials had produced very conclusive results, they were, therefore, discontinued in 1961.

It was found that rice yield did not differ when the rate of seeding within the range of 120 - 180 kgs per hectare was used. However, it seemed preferable to use 180 kgs as a cushion against poor germination which usually occurs when the soil or water is saline.

Experimental results had shown that rice should be sown neither after the 15th of May nor before the 20th of April, because when planted too late the salinity of the irrigation water would be too high for the development of the young seedlings, and when planted too early the temperature would be too low for the normal germination of the seeds.

Both sulfur and gypsum were used in a trial aiming at amending the soil which is assumed to contain sodium carbonate brought into the land by the irrigation water. In both 1959 and 1960, however, negative results were obtained. Rice yield was not improved by the application of either gypsum, or sulfur or both, which indicated indirectly that the Medjerda water did not contain insoluble salts in any appreciable quantity. Insoluble salts are much more harmful to crop plants than soluble salts, and they can be removed only by chemical treatment of using sulfur or gypsum. Fortunately, the results of this trial have demonstrated that such treatment was not necessary. As a matter of fact the application of sulfur and or gypsum has decreased the rice yield probably due to certain unknown toxic effect on the germination of the seeds.

VIII. Rice growing by pumping irrigation

There is a large quantity of water in an estimated amount of 1 - 3 cubic meters per second flowing to the sea unused. If rice is grown in fields located near the river-side of the Medjerda, it can be irrigated by pumping the water directly from the river without the necessity of drawing the water from the irrigation canal. Furthermore if the rice fields are so located, there would be of no need to dig any drainage ditches, as the river-bed itself can serve as the natural drainage canal.

Thus, a piece of land of about 3 hectares at the northern bank of the river at Kontert Bizerte was planted to rice in 1961. It was irrigated by pumping with a small motor pump. The cost of pumping the water from the river averaged at only 1.2 millimes per cubic meter.

All land preparations including plowing, disking, levelling, and dyke construction were made by tractors. As both potash and phosphorus do not [redacted] give any effect on rice yield, only Ammonium sulphate was used at the rate of 300 kgs per hectare.

Unfortunately the rice crop was found not growing very well in this field, producing only 1,042 kgs of paddy at an average yield of only 0.30 ton per hectare. This was a very low yield as compared with 2.51 tons per hectare obtained in Bejaoua in the same year.

This low yield seemed to have been caused by two factors, namely, (1) higher salt concentration in the water, and (2) insufficient drainage.

Water samples were taken simultaneously twice a month throughout the season from the pumping site at Kontert Bizerte and from the irrigation canal at Bejaoua. Their electrical conductivities were tested.

Table 11. Salt concentration of the water at Kontert Bizerte and at Bejaoua

Months	At Bejaoua	At Kontert Bizerte
	in millimhos	
May	5.06	5.67
June	4.44	4.97
July	4.21	4.23
August	4.90	5.31
September	4.59	5.25
Average	4.64	5.09

The salt concentration of the water at Kontert Bizerte was found to be 5.09 millimhos as compared with only 4.64 millimhos at Bejaoua. The water in the irrigation canal at Bejaoua comes from the river beyond the barrage at Arroussia by gravity flow, and the water pumped from the river at Kontert Bizerte has mixed with drainage water flowing to the river from various parts of the valley. As drainage water carries much more salt, a mixture with such water would naturally increase its salt concentration.

Although salt concentration of the water at Kontert Bizerte increased from 4.64 millimhos as at Bejaoua to 5.09 millimhos, representing an increase of only some 9 percent, rice yields decreased from 2.51 tons to only 0.30 ton per hectare. This shows that when the salt concentration of a water has already reached a very high level, the ill effect of any additional salt in such water would be much greater than that at a lower level. In other words, salt effect on rice yield is not proportional or linear but cumulative or curvilinear.

It was also found that drainage was not sufficient in this field as evidenced by the fact that the total quantity of water irrigated to this field amounted to only 25,000 cubic meters per hectare as compared with 45,000 cubic meters at Bejaoua. As a result of both insufficient drainage and higher salt concentration of the irrigation water, salt deposit in the soil in this field was much higher than that in the rice fields in Bejaoua.

Table 12. Salt deposit in the soil at Bejaoua and at Kontart Bizerte

Places	Soil samples taken at 4 weeks after sowing	after harvesting	Average
Bejaoua	3.75	4.10	3.92
Kontart Bizerte	7.10	7.50	7.30

The average soil salinity at Kontart Bizerte amounted to 7.30 millimhos against only 3.92 at Bejaoua. This increased soil salinity at Kontart Bizerte, which might have resulted from lack of drainage as well as from higher salt concentration of the irrigation water, has lowered the rice yield down to only 300 kg per hectare. From this result it seems that soil salinity of over 4 millimhos may be too high to produce a satisfactory crop of rice.

IX. A study on the cost of production

In 1961 rice was grown in two regions with two different systems of irrigation, namely (1) in Habibia, Bejaoua and Habous Cherif totalling 19.4 hectares with irrigation by gravity flow, and (2) in Kontart Bizerte totalling 3 hectares with irrigation by direct pumping the water from the river.

The cost of each operation from sowing to harvesting was carefully recorded in both regions, and the results are given below:

Table 12. Cost of production of rice in 1961

Items	At Kontart Bizerte by pumping irrigation: Total cost for 3 hectares	Av. cost per ha.	At other regions by gravity irrigation: Total cost 19.4 ha	Av. cost per ha.
Plowing	13.000	4.333	56.000	2.886
Disking	6.000	2.000	53.000	2.732
Levelling	24.250	8.083	14.500	0.747
Fertilizers	21.600	7.200	418.037	21.548
Manures	---	---	58.000	2.990
Amm. sulfate	21.600	7.200	171.696	8.850
S'phosphate	---	---	125.388	6.463
P. sulphate	---	---	62.153	3.204
Seeds	17.500	5.850	141.120	7.276
Wages	70.700	23.567	1,609.450	82.961
Harvesting	27.000	9.000	387.950	19.997
Subtotal	180.100	60.033	2,680.057	138.147
Irrigation water	89.760	29.920	1,767.506	91.108
TOTAL	269.860	89.953	4,447.563	229.255

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All land preparations including plowing, disking and levelling were done by a Ferguson 65, and the cost of its operation was reckoned at 500 millimes per hour. The price of fertilizers was recorded at 1.400 dinars per ton of manure, 24 millimes per kg of ammonium sulphate, 11.9 millimes per kg of superphosphate, and 36 millimes per kg of potassium sulphate. Seeds although produced by this Service in 1961, was estimated at 45 millimes per kilogram. Wages covered all man-labor operations including sowing, weeding, spraying of fertilizers, and irrigation, and was reckoned at 350 millimes per man-day. Rice was harvested by a Claas combine, and the cost of its operation was 2.500 dinars per hour. The pumping of water at Kontert Bizerte totalled 748 hours at an average capacity of 25 - 30 litres per second estimated at 1.2 millimes per cubic meter. Irrigation water by gravity flow cost 2 millimes per cubic meter.

According to the data given in the above table, the total cost of production in Kontert Bizerte was found to be 89.953 dinars per hectare against 229.255 dinars in the other regions. The main part of this difference lies in the cost of wages and water. In Kontert Bizerte, wage cost amounted to only 23.567 dinars per hectare in comparison with 82.961 dinars in the other regions. This difference was attributed to the fact that rice in Kontert Bizerte was grown only for production whereas in the other regions it was grown for both production and experimentation. Much more labors would be needed to nurse the rice grown in an experimental plot than in a large field, which thus increased the cost in wages. The cost of the irrigation water was 29.920 dinars per hectare in Kontert Bizerte and 91.708 dinars per hectare in the other regions because of their difference in the quantity of water irrigated as well as in the price of the water.

It thus becomes obvious that if rice is to be grown by pumping irrigation, it will need to produce slightly over 2 tons of paddy in order to cover its cost of production of 90 dinars per hectare, and that if rice is to be grown by gravity irrigation provided with a good system of drainage, it would need 3.8 tons of paddy to equal the cost of production of 150 dinars per hectare which consisted of 90 dinars for irrigation water and 60 dinars for all the other operations as incurred in Kontert Bizerte.

In 1960 when the rainfall was normal, the salt concentration of the water averaged at 3.2 millimhos and rice yielded 5.55 tons per hectare. If reckoned at a 10 percent increase, the salinity of the water in Kontert Bizerte in 1960 would have then been at most 3.6 millimhos. At this level rice yield could be expected well over two tons per hectare.

If we have a normal year of rainfall, the salt concentration of the irrigation water could be expected to be low enough to produce a profitable crop of rice either by gravity irrigation or by pumping irrigation. Such expectation, however, is made only on the basis of the data obtained during the last 3 years, and should, therefore, be confirmed by further studies in years to come.

X. CONCLUSION

Notwithstanding that crop yields in 1961 were very low due to lack of rainfall, which in turn has increased the salt concentration of the water, it has given us a good opportunity to tackle the very important problems of how rainfall has related to the salinity of the water and of how the salinity of the water has affected the yields of the crops. Although rice is found not to be the most salt tolerant crop, it certainly belongs

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to the tolerant group. In normal years the salt concentration of the Medjerda water could be expected to be low enough to produce a prifitable crop of rice, which we have found during the last three years the proper methods to grow in the Medjerda Valley. It seems that the problems presented in this report are of prime importance not only for the development of rice cultivation but also for the improvement of agricultural production in general.

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