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Integrated Management Package to Maximize Productivity of Forage Pearl Millet Under Marginal Soil and Water Resources of North Sinai – Egypt

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ABSTRACT

A field experiment was carried out, at El-Tina Plain, North Sinai Governorate, Egypt, during the two summer growing seasons 2014 and 2015. This work was conducted to study the effect of improved management package (IMP) using two surface irrigation methods as flow management (continuous and surge flow) IMP_C and IMP_S, respectively, and three foliar applications by urea treatments (0, 1.0, and 2.0% N) f_1, f_2 and f_3, respectively, on some growth characters and forage yield of pearl millet (*Pennisetum glaucum L. R. Br*). Obtained results showed that the growth characters and forage yield of pearl millet, i.e. plant height, the number of tillers m^{-2}, and totally fresh and dry weight yield increased significantly by IMP, produced the highest significant values of the most growth characters and the totally fresh and dry forage weight. Meantime, the growth traits and forage dry yield were significantly affected by using 2% of urea foliar application (f_3) treatment which produced the highest values of plant height, tillers m^{-2}, and total fresh and dry weights ha^{-1} compared to short furrows (TMP_{sf}). Water-saving is greatly enhanced by using the surge flow technique of irrigation water management (IMP_S). The highest mean value of the irrigation water use efficiency by total fresh forage yield ($IWUE_f$) obtained 13.26 kg m^{-3} by IMP_Sf_3 treatment, while by total dry yield ($IWUE_d$) obtained 2.81 kg m^{-3} by IMP_Sf_2 treatment.

***Keywords**:* Integrated management package – long furrows - surge flow – N foliar apply - maximize productivity - forage pearl millet - marginal resources

INTRODUCTION

Salinization of soils or water is one of the world's most serious environmental problems in agriculture. It is necessary to determine the environmental factors under which plants give higher yields and better quality. Siddique *et al.*, (1990) noticed that about 30-60% of the seasonal evapotranspiration may be lost as evaporation from the soil surface beneath crops grown in Mediterranean climates which is important in influencing crop yield. Thus, the improvement of salt tolerance by alters some environmental factors may also greatly increase water use efficiency for plant growth and/or reduced the quantity of water required.

Certainly, more work needs to be done on these relationships. The problem of salinity is characterized by an excess of inorganic salts and is common in the arid and semi-arid lands, where it has been naturally formed under the prevailing climatic conditions and due to higher rates of evapotranspiration and lack of leaching water, Jouyban (2012). Yakubu *et al.*, (2010) reported that germination percentage, plant height, shoot and root dry weights of some millet varieties were significantly decreased with increasing soil salinization. Increased NaCl concentration has been reported to induce increases in Na and Cl as well as decreases in N, P, Ca, K and Mg level in plants, Abd El-Wahab (2006). Hassan *et al.*, (2016) evaluated the utilization of the proper soil N dose with supplementary by foliar application of urea to avoid the increase of soil salinity, they found that nutrient disturbance under salinity reduces plant growth by affecting the availability, transport, and partitioning of nutrients. However, salinity can differentially affect the mineral nutrition of plants, therefore, supplementary foliar application of N may be helpful to minimize soil application and consequently to reduce the impact of salinity stress. Pearl millet is a robust, and quick-growing plant. However, Krishnamurthy *et al.*, (2007) showed that pearl millet is rated to be moderately tolerant to salinity.

Today in Egypt, with the continuous occurrence of green forage shortage during summer seasons, increasing the productivity of some promising annual forage types is getting interested. The growth and yield of pearl millet can be enriched only through efficient agronomy intervention. Shahin *et al.*, (2013) founded that Shandaweel-1 var. resulted from the highest fresh yield and the tallest plants at all cuts with increasing nitrogen rates up to 143 kg N ha^{-1} in both seasons except, at the 3rd cut in the first season. Generally, the mineral fertilizer applied with organic amendment increased soil nutrients availability, which resulted from high yield production, Abd El-Lattief (2011).

Abd EL-Azim and Ahmed (2009) reported that a significant effect on plant height, fresh and dry weight $plant^{-1}$, fresh yield ha^{-1}, crude protein, total ash, potassium, and sodium contents through the interaction between salinity and cutting date. Hiekal *et al.*, (2016) concluded that establishing an integrated management package and

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developed an irrigation system for forage sorghum production are considered the best way to overcoming the shortage in animal feed, especially in the marginal areas; through mitigating salinity hazards. It can be recommended that develop the field irrigation system (surface irrigation system) and change it to the long furrow irrigation system, through spill pipes proposed in this study, to avoid the problems of the salinity and consequently avoid desertification. The results may be helpful in sustainably enhancing crop productivity and provide an opportunity to attain a level of food security for poor farmers in saline areas. Ziki *et al.,* (2019) concluded that the forage cutting date was found to be a determinant factor that affects to a great extent the regrowth habit as well as yield of forage crops. It was established that early cutting would trigger crop regrowth, while delayed cutting tends to produce a higher yield, Bukhari *et al.,* (2011) and Raval *et al.,* (2014). Kumar *et al.,* (2012) found that the greatest effect on fodder yield and quality is by the optimum plant density, sowing date, crop cutting management, fertilizer, irrigation, and plant protection measures.

The problem of low soil infiltration rate, which causes an elongated time of water ponding on the soil surface and may cause aeration deficiency of crops. Surface irrigation methods will stay the general ways of water application especially furrow irrigation, it could be the best surface irrigation technique that can decrease wetting area, enhancing root zone aeration, and maximizing the crop yield, Doorenbos and Pruitt (1977). Many methods are valuable to enhance water use efficiency by a developed surface irrigation system. Hiekal (2007) concluded that the surge furrow irrigation (SFI) technique is a selection of low cost and it is important to developing areas to save water and time of irrigation. However, SFI increases water application efficiency (Ea%), distribution uniformity (DU), and IWUE. By good water distribution in the soil profile than that in a conventional way which less water was lost by deep percolation at long furrow's length, especially at start irrigation events. Moreover, the difference in yield is sufficient to invite farmers to do further work to changing the conventional irrigation practices. The best combination of irrigation and nitrogen management to realize acceptable pearl millet forage both in quantity and quality aspects, in which water is practically limited, applied of 150 kg N ha^{-1} can produce high forage quality and acceptable benefits for farmers, Rostamza *et al.,* (2011) and Raval *et al.,* (2014).

The field experiment was conducted to enhance forage yield of pearl millet (fresh and dry) under salt-affected conditions, through a better management package affected by suitable irrigation management method and consequent nitrogen fertilization as a foliar spray, and evaluate surge flow irrigation and water management practices on both productivity and irrigation water use efficiency by long furrows, and assess the Nitrogen foliar spray and irrigation water distribution uniformity on the growth and yield of forage pearl millet.

MATERIALS AND METHODS

Experimental location, design and treatments

A field experiment was conducted at El-Tina Plain, North Sinai Governorate, Egypt, the location of a private farm sited at a Latitude of 31° 0' 41.12'' N and longitude of 32° 29' 30.14''E during two successive summer seasons of 2014 and 2015. Two management packages were carried out as follows: traditional management practices (TMP_{sf}) under irrigation by short furrows in basins (4.5x15 m) will be denoted as (TMP_{sf}) as farmer practices and improved management practices (IMP) under irrigation by long furrows system (90 m) using spill control pipes with two irrigation management methods by surge flow irrigation (S) and continues flow irrigation (C), which are abbreviated with improved management practices treatments as (IMP_S) and (IMP_C), respectively**.** The experiment laid out in a complete randomized block design comprising four replicates, IMP_S and IMP_C have occupied the main plots (2 x 810 m^2) areas and foliar sprays by urea were allocated in sub-plots. Each sub-plot contains three furrows, 75 cm apart, with 22.5 m of plot length (50.63 m^2).

The soil type of experimental site was clay loam in 0-120 cm of the soil profile and Table (1) shows some soil physical properties analysis according to the methods described by Klute (1986) before sowing in the first season. The average field capacity of root-zone (v%) was 17.28%.

Definitions of some soil chemical properties according to the methods described by Black (1983) at different soil layers are shown in Table (2), the top 30 cm of the soil has low in organic matter (OM) 0.3 %., the nutrient composition was low in total nitrogen (0.12 %), available phosphorus (8.0 ppm) and available potash (0.73 meq. 100g $soil^{-1}$). The pH was 7.6 and the electrical conductivity was 6.57 dS m^{-1}. The previous crop was Egyptian clover in each season.

Table 1. Some physical properties of the experimental soil site (before planting in 1st. season)

Soil depth (cm)	Coarse sand	Fine sand	silt	Clay	Bulk density (g cm^{-3})	Texture class	Field Capacity	Wilting point	Available water
	(%)						(v%)		
0 -30	10.44	30.06	27.50	32.00	1.45	Clay loam	25.10	8.02	17.08
30-60	7.46	33.44	30.60	28.50	1.51		24.80	7.92	16.88
60-90	5.84	29.06	35.00	30.10	1.53		23.90	6.01	17.89
90-120	7.50	35.000	29.500	28.000	1.52		24.00	7.75	16.25

Table 2. Some chemical properties of experimental soil site (before planting in 1st. season)

Soil depth (cm)	pH	SAR	EC (dS m^{-1})	Soluble Cations (mg L^{-1})				Soluble Anions (mg L^{-1})			OM (%)	Total N (%)	Ava. P (ppm)	Exch. K (meq.100g $soil^{-1}$)
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}				
0 -30	7.6	9.2	6.57	9.5	12.4	42.9	0.8	7.0	36.9	21.9	0.3	0.12	8.0	0.73
30-60	8.0	9.1	7.7	9.9	18.0	48.0	1.0	9.7	39.9	27.4	0.4	0.2	9.1	1.0
60-90	7.3	11.8	10.1	11.9	20.3	67.2	1.3	11.7	60.0	29.0	0.3	0.1	11.2	1.0
90-120	7.1	10.1	8.1	10.4	16.9	52.7	1.0	9.4	45.6	26.1	0.2	0.1	13.1	2.1

In El-Tina Plain area, irrigation water is available from El-Salam Canal (Nile water mixed with drainage water from Bahr Hadous and El- Serw drains). The analysis of irrigation water samples obtained from the El-Salam Canal was carried out as shown in Table (3). Data showed that salinity value according to the collected samples ranged between 2.61 to 2.54 dS m^{-1}, with an average value of 2.58 dS m^{-1} for two seasons. This indicated that water salinity ranges in a slightly saline category. Sodium is the dominant cation, where its mean value of 13.7 meq L^{-1}. Chloride is the dominant anion, where its mean value is 14.95 meq L^{-1}.

Table 3. Some chemical properties of irrigation water (Mean values).

PH	EC (dS m^{-1})	TDS (mg L^{-1})	Soluble Cations (meq L^{-1})				Soluble Anions (meq L^{-1})			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	Cl^-	$SO_4^=$	NO_3^-
7.53	2.58	1637	5.01	7.01	13.7	0.11	6.51	14.95	4.11	0.23

Under the TMP_{sf}, the farmer prepared and managed his farm as usual seasonally, which included the addition of farmyard manure at an average rate of 7 $m^3.ha^{-1}$ during soil preparation, tillage at 20 cm with chisel plow 7 blades (two passes), and addition of ammonium nitrate or urea at the rate of 150 or 100 kg ha^{-1}, respectively, as well as establish the short furrows in small basins with applying a rate of pearl millet seeds of 85 kg ha^{-1} as local cultivar Shandweel 1, (*Pennisetum glaucum L., R. Br.*), seeds were sown on 1st. May, during two seasons by laborers.

While through IMP treatments, at each season, besides the addition of salt leaching requirements, solid farmyard manure (FYM) was added, and the effective microorganisms solution (EM) with the rate of 60 m^3 ha^{-1} and 50 L ha^{-1}, respectively, after plowing and leveling of the land surface using the LASER technique with a longitudinal slope of 0.1 % to establish long furrows irrigation system of the spill pipes with spacing 75 cm apart. Applying the rate of pearl millet seeds of 60 kg ha^{-1} from the same local cultivar Shandweel 1, seeds were sown on 1st. May, each season using drill method in double row slopping beds of furrows. The plant spacing of an average of 7.5 cm on both sides of the ridge furrows. The plants' density was 355555 plant ha^{-1} on average. Some physicochemical properties of the analytical composition of the FYM are given in Table (4).

Table 4. Some mean values of the FYM properties (2014 and 2015).

Bulk density[a]	pH[b]	EC	C: N	WHC[c]	OM*	N	C	P	K	Ca	Mg	Fe	Mn	Zn	Cu
(Mg m^{-3})		(dS m^{-1})		(g kg^{-1})								(mg kg^{-1})			
0.44	8.01	2.94	23.93	309	48.6	11.8	282.4	8.3	9.0	7.1	9.8	2524.6	276.2	112.0	28.0

[a] Oven dry-weight basis. [b] FYM : Moisture = 1:5 * Organic matter
[c] Water holding capacity was the difference of moisture content (weight %) between −0.33 and −15 bar pressure.

Soil moisture characteristic:

Soil moisture properties of the experiment area were determined in the undisturbed soil cores, as the methods described by Reynolds and Topp (2007). Because the infiltrated volume of irrigation water must be close to the volume applied to the soil due to the use of blocked-end furrows, the volume balance technique was applied to determine the infiltration rate, Walker (1989). The basic infiltration rate was 19.2 mm h^{-1} determined by a double-ring infiltrometer, which measured primarily the vertical rate of water movement into the soil surface (one-dimensional). The field infiltration tests were conducted for the desired period at three random locations in the experiment area.

Irrigation treatments and scheduling

The irrigation treatments of three irrigation methods (TMP_{sf}), (IMP_S), and (IMP_C) were occupied under management practices. Irrigation was applied at 9-12 days intervals when the available soil moisture content was depleted to nearly 50% in the 0.8 m soil profile depth "root zone" (Martin *et al.*, 1990 and Allen *et al.*, 1998). The inflow rates were checked through volumetric methods according to the technique of Hiekal (2007). The TMP_{sf} flow rate was 468 L $min.^{-1}$ $basin^{-1}$ on an average in small basins (4.5 x 15m) 67.5 m^2 (6 furrows each basin) in four replicates. While IMPs and IMP_C were prepared by the research team which installs one spill pipe for each furrow to supplied water to two rows of plants. Each treatment (three adjacent furrows) was 90 m in length, with 4 replicates. The inflow rate was in an average of 120 L min^{-1} $furrow^{-1}$ in both IMP_S and IMP_C treatments. Each cycle time in IMP_S treatment was 60 min (15 min ON and 45 min OFF) with a cycle ratio of 0.25 each irrigation event was in 4 cycles. While IMP_C treatment, the irrigation cutoff time was at 100 min., and irrigation runoff was negligible, which the furrows were closed-ends in all treatments of IMP. Thus, the net of irrigation water was the amount of water added to the field. The amounts applied during each irrigation event matched the crop's growth stage. Table (5) shows the dates of the irrigation schedule by IMP.

Table 5. Schedule of IMP treatments as dates after sowing (DAS) for irrigation events, N dose, urea foliar spray, and forage cuts during grown forage pearl millet in successive growing seasons of 2014 and 2015.

DAS	Irrigation event	N dose	Urea foliar app.	forage cut
1-2 May	1st	…	…	…
12	2nd	1st	…	…
24	3rd	…	1st	…
35	4th	…	…	…
44-46	5th	…	…	1st
56	6th	2nd	…	…
66	7th	…	2nd	…
75	8th	…	…	…
84-85	9th	3rd	…	2nd
94	10th	…	3rd	…
104	11th	…	…	…
116-117		…	…	3rd

Fertilizer applications

All the cultural practices were operated as mentioned above in all plots uniformly under IMP treatments beside additional 250 kg ha^{-1} of mineral sulfur as amendments during land preparation, the crop was treated based on soil analysis with recommended doses of NPK (120-75-50 kg ha^{-1}) before sowing as basal doses in the form of ammonium sulfate (20.5%), calcium superphosphate (15.5% P_2O_5) and potassium sulfate (48 % K_2O), respectively. Except the N fertilizer was added in three equal doses, the doses were applied as shown in Table (5) just before the irrigation events, and the other cultural practices for the crop were applied according to the Ministry of Agriculture recommendations. The plants in subplot treatments were sprayed with different levels of foliar urea (46% N) by 0.0, 1.0, and 2.0% urea as subplots denoted as f_1, f_2, and f_3, respectively, f_1 sprayed by water, while no foliar spray with $TMP_{sf}f_0$ as absolute control. This method was applied in the schedule as shown in Table (5) at a rate of 600 L ha^{-1} using a hand sprayer of 20 L size.

Soil water content and irrigation water management

Changes in soil water status were monitored, to evaluate the soil moisture distribution and irrigation performance based on the soil moisture content, it measured according to Merriam *et al*., (1983) before and after of $1^{st.}$, $5^{th.}$ and $9^{th.}$ irrigation events to a depth of 1m with 0.2 m increments. Irrigation water applied was appropriate to the crop's growth stage according to the methodology as described by Doorenbos and Pruitt (1977), it calculated according to the equation:

$$IWA = ((A * ETc * Ii)/(Ea * 100)) + LR,$$

where: **IWA = Irrigation water applied (m^3), A = Plot area (m^2), ET_c = Crop water requirements (mm day^{-1}), I_i = Irrigation intervals (day), Ea = Application efficiency (%), and LR = Leaching requirements (m^3).**

Under field conditions and water qualities, LR was added as 15 % of water requirements. The deficit of soil moisture (SMD) was determined by a gravimetric method according to Howell and Meron (2007) one day before the irrigations in the middle furrow of each plot at four locations along furrow length. Average monthly reference evapotranspiration (ET_o) values during the cultivation seasons are shown in Table (6). The crop factor (k_c) was 0.4, 1.05, and 1.15 after cutting, between cutting and before cutting, respectively.

Table 6. average monthly reference evapotranspiration (ET_o) values during the growing seasons.

Season	ET_o (mm $month^{-1}$)			
	May	Jun	Jul	Aug
2014	5.58	5.88	6.77	7.18
2015	5.49	5.96	6.37	6.92

Irrigation water application efficiency (Ea%):

Application efficiency (Ea%) were calculated for the 80 cm soil depth according to James (1988) as an average value of 1^{st}, $5^{th.}$ and 9^{th} irrigation events according to the equation:

$$Ea\% = ((W_s/W_f)*100)$$

where: **Ea% = water application efficiency, (%), W_s= amount of water stored in the root zone, (m^3), and W_f= amount of water added to each plot, (m^3).**

Distribution uniformity (DU):

Water distribution uniformity (DU) is a ratio of the smallest accumulated depths in the distribution to the average depths of the whole distribution. A commonly used fraction in the lower quarter. The average accumulated water depth in the quarter of the field receiving the smallest depths is given by Burt *et al*., (1997):

$$d_{lq} = \frac{\textit{volume acumulated in 25\% of total area of all elements with smallest depths}}{\textit{total area of 25\% of the total area of elements}}$$

d_{lq} = volume accumulated in 25% of the total area of all elements with the smallest depths divided by the total area of 25% of the total area of elements. From this, the low-quarter distribution uniformity, DU_{lq}, can be defined as:

$$DU_{lq} = \frac{d_{lq}}{d_{avg.}}$$

where: **d_{avg} is the total volume accumulated in all elements or observations [m^3] divided by the total area of all the elements [m^2].**

Cutting management and biomass sampling

Forage cuts were made each time as showed dates in Table (5). So, there were three harvests. At the time of each cut, which was manually cut with a sickle 7 cm over the soil surface and the total yield per cut per plot was weighed.

The first cut occurred 45 days after sowing (DAS), and a 35-day interval was left between each of the two following cuts up to the third cut. An area of 2.5 m^2 for each cut was harvested by hand. After recording the fresh weight of the total sample in the field, 2 kg was taken as a subsample were divided into leaf and stem. Plant parts were oven-dried for 2 days at 80°C and then the total dry matter was calculated.

Irrigation water use efficiency calculations

Irrigation water use efficiency (IWUE) was measured according to James (1988) as follows:

$$IWUE = \frac{Y}{W_a}$$

where: **IWUE = irrigation water use efficiency, kg m^{-3}, Y = total fresh or dry yield, kg ha^{-1}, and W_a = total applied water, m^3 ha^{-1}.**

Statistical analysis:

The experiment was laid out in a complete randomized blocked design with four replications having a split-plot arrangement. Data from 2014 and 2015 growing seasons are presented and discussed as average, because the test of homogeneity of variance, Winer (1962), when performed, revealed that the error of the variance between the two experimental seasons was homogeneous. The number of replicates for each treatment was four. All data were subjected to the proper statistical analysis of variance according to the procedure outlined by Steel and Torrie, (1960). The mean values were compared at 0.05 level of probability by least significant differences (LSD) test using Duncan's multiple range test was used to determine the significance of differences by Statistica Enterprise 10 Version. In the interaction Tables, small letters were used for comparison among column means.

RESULTS AND DISCUSSION

One of the challenges for research is to understand the water-nutrient interactions for forage cropping systems and to integrate this information as tools that can assist makers in production management decisions that will lead to improving both IWUE and nutrient use efficiency, nitrogen fertilizer plays an important role in enhancing plant dry matter that had a positive effect on crop yield, as clarified by Fayed *et al.*, (2016), besides enhancing water distribution, results will reveal how management package affect biomass of forage yield in marginal conditions.

Performance of Irrigation method:

The performance parameters of the irrigation method were evaluated and the data is signed in Figs. (1 A & B). These parameters are water application efficiency (Ea%), and the low-quarter distribution uniformity (DU_{lq}). Data in Fig. (1-A) showed the average mean values of Ea% for growing seasons 2014 and 2015 with TMP_{sf} treatment were ranged from 80.7 to 81.6 %, it is clear that about 18.4 –19.3% of the water applied was non-useful or un-valuable for the crop and lost by deep percolation, but among the other treatments, the average values of Ea% under IMP_C ranged from 87.7 to 91.9%. in the meantime, these values with IMP_S treatment were ranged from 92.1 to 93.3%. The Ea% was directly proportional to the length of the field and inversely proportional to the inflow rates and the time of irrigation.

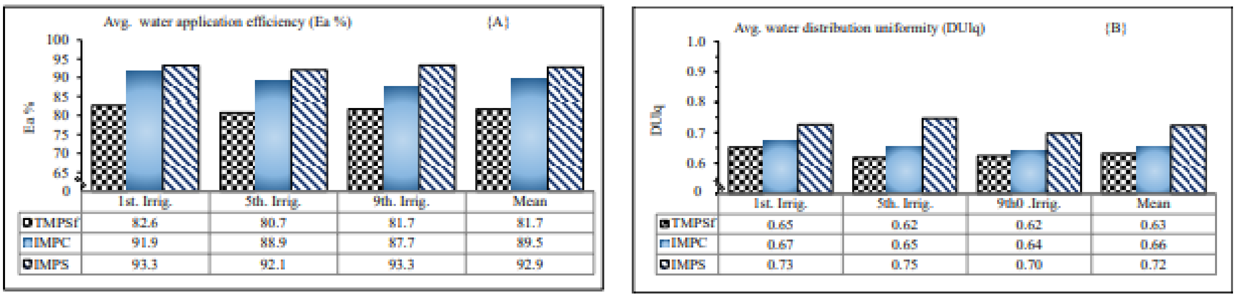

Fig. 1. Average water application efficiency, Ea % {A}, and low-quarter distribution uniformity, DU_{lq} {B} for considered management practices IMP_S and IMP_C compared to TMP_{sf} (Mean of three irrigation events in the two growing seasons 2014 and 2015)

The uniformity of the applied water concerning the requirements of the crop, Pereira (1999). However, many soil and crop combinations require a certain volume of applied water to be drained from the bottom of the profile to prevent salt accumulation. Where leaching is imperative it will impose an upper limit on the application efficiency, Smith *et al.*, (2011).

Concerning the low-quarter distribution uniformity (DU_{lq}), data in Fig. (1-B) illustrated similar trends for that the water application efficiency when use improved soil and water management practices for cultivation forage pearl millet crop under marginal conditions. Values of DU_{lq}, with TMP_{sf} treatment, were ranged from 0.62 to 0.65, while under IMP_C treatment, ranged from 0.64 to 0.67. In the meantime, average values of DU_{lq} with IMP_S treatment ranged from 0.7 to 0.75. The highest mean values of water application efficiency Ea% and DU_{lq} are achieved with improved management practices IMP_S, which their average values during two growing seasons reached 92.9% and 0.72, respectively, followed by IMP_C (89.5%, and 0.66, respectively). DU_{lq} increment value percentages for IMP_C and IMP_S were 3.75 and14.55%, respectively compared with TMP_{sf} treatment. Therefore, one of the very first steps in evaluating and improving on-farm irrigation efficiency is often obtained by a field evaluation of the *DU* of an irrigation system, Burt *et al.*, (1997).

Applied irrigation amounts and water saving:

The most appropriate irrigation management must fulfill both requirements of high yields and high crop water productivity "CWP", Pereira *et al.*, (2012). By the way, the average yield and CWP for different irrigation treatments were characterized as the criteria for investigating the considered irrigation management practices. The referred values were applied as mean amounts of both seasons showed in Fig. (2). The average water used for considered management package treatments as means of the two growing seasons 2014 and 2015 showed in Fig. (2), the effect of IMP was obviously with rationalizing irrigation water compared with the TMP_{sf} which IMP_S treatment used an average of 11860 m^3 ha^{-1}, applied IMP_S treatment conserved amounts of irrigation water about 22.5% compared with TMP_{sf}. While with IMP_C, it was clear that the conservation percentage was about 12.5% compared with TMP_{sf} during the two growing seasons.

The details of water-saving between IMP_S and IMP_C treatments compared with TMP_{sf} were highly significant, the mean obtained percentage 23.5 and 13.4 %, respectively in $1^{st.}$ cut, and it was 31.2 and11.6 %, respectively in $2^{nd.}$ cut, except in $3^{rd.}$ cut, it was non-significant differences which were 12.6 and 12.3 %, respectively.

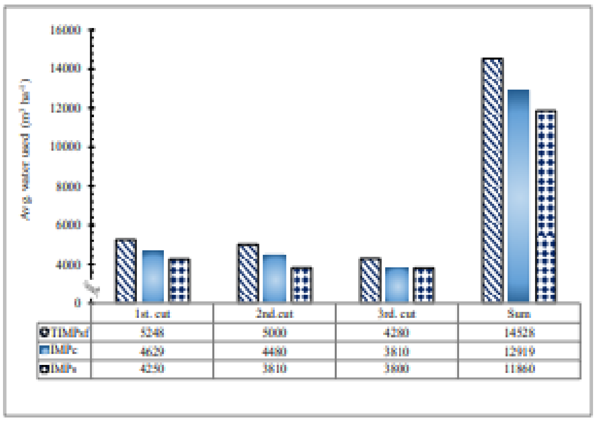

Fig. 2. Average water used for considered management package treatments (Mean of the two growing seasons of 2014 and 2015)

From mentioned results, the water balance is affected by both crop and soil management. Using the proper amount of irrigation water and when need-based on plant requirements and its application with site specific technique can ensure practical improvements in water use efficiency (Pereira *et al.*, 2012 and Raza *et al.*, 2012).

Management practices methods and some growth parameters

The effects of considered methods on growth parameters including plant height, and the number of tillers m^{-2} are showed in Table (7), which indicated that f_3 treatment under IMP resulted from a significant increase in the average plant height under the three cuts compared with f_0 under TMP_{sf}. However, in 2nd. cut, the increase was not significant compared with f_2 under IMP_C treatments, also, between f_1 and f_2 under IMP_S. Plants were higher in the second cut than in the first or third one. Results also showed that cultivating during May offers the opportunity to complete the temperature requirement of millets. Completing temperature requirements increased the number of tillers and plant height and consequently resulted in high yield, Shahin *et al.*, (2013) came to a similar conclusion. Generally, by IMP_Sf_3 treatment increased the average number of tillers compared to the other treatments by three cuts, the number of tillers was increased with the increase of N foliar spray with good water distribution uniformity as mentioned before. These increments in an average of three cuts were 27.9, 25.0, 22.3, 20.6, and 8.4% as combined results in the three cuts by IMP_Sf_3, IMP_Cf_3, IMP_Cf_2, IMP_Sf_2, and IMP_Sf_1, respectively, as compared with the control treatment ($TMPf_0$) with non-significant between IMP_Sf_1, and IMP_Cf_1.

Table 7. Effect of management practices, water application method and foliar spray treatments on pearl millet plant height and number of tillers at 1st., 2nd. and 3rd. Cuts (Mean values of the seasons 2014 & 2015)

Growth characteristics	Treatment	Cut			
		1st.	2nd.	3rd.	Mean
Plant height (cm)	$TMP_{sf}f_0$	94.00e	113.00c	91.50cd	99.50 d
	IMP_Cf_1	96.90d	104.60d	94.60c	98.70 d
	IMP_Cf_2	126.15c	152.30a	103.10b	127.18 b
	IMP_Cf_3	130.35b	151.50a	110.80a	130.88 a
	IMP_Sf_1	130.70b	133.10b	87.60d	117.13 c
	IMP_Sf_2	126.15c	136.90b	94.20c	119.08 c
	IMP_Sf_3	138.05a	152.30a	94.60c	128.32 ab
LSD P = 0.05		1.48	3.56	3.33	1.42
Number of tillers m^{-2}	$TMP_{sf}f_0$	78.10e	89.30e	89.75c	85.72e
	IMP_Cf_1	91.10d	94.70de	93.37bc	93.06 d
	IMP_Cf_2	105.15b	112.00bc	113.81a	110.32 bc
	IMP_Cf_3	105.05b	120.00ab	117.59a	114.21 b
	IMP_Sf_1	81.30e	101.00d	98.55b	93.62 d
	IMP_Sf_2	96.45c	110.90c	116.46a	107.94 c
	IMP_Sf_3	112.95a	124.00a	119.58a	118.84 a
LSD P = 0.05		2.3218	3.8476	3.3735	2.14

Means followed by the same small letters within columns were not significant at 5% probability level.

Management practices methods and fresh and dry forage yield

Results presented in Table (8) and Fig. (3) showed the effect of irrigation methods and foliar spray of urea fertilizer by IMP on pearl millet forage crop fresh and dry yields at 3 cuts. N foliar sprays and enhancing irrigation methods with IMP treatments attained significant increments more than that recorded by TMP_{sf} in fresh or dry forage yields.

Mostly, with increasing foliar nitrogen application and enhancing irrigation performance under IMP treatments, fresh yield ha^{-1} increased. These increments were significant values obtained by IMP_Sf_3 (28.6%), which were non-significant differences values (25.0, 24.5, and 22.8%) obtained by IMP_Sf_2, IMP_Cf_2, and IMP_Cf_3, respectively, by comparing with control treatment ($TMP_{sf}f_0$). These increments in fresh yield may be due to the increases in plant height, and the number of the tillers m^{-2} as foliar nitrogen application rates increased, and water distribution uniformity in the root zone along the field.

While the effect of enhancing irrigation performance under IMP treatments on fresh yield ha^{-1} showed it was significant values increments 5.8 and 16.0% obtained by IMP_Cf_1 and IMP_Sf_1, respectively, compared with TMP_{sf} f_0. These increments in fresh yield may be due to enhancing the irrigation water distribution uniformity consequently the increases in plant height, and the number of the tillers m^{-2} with foliar nitrogen application rates increased. Similar results have been observed, where lower irrigation performance created a lower crop yield and vice versa (Ayub *et al.*, 2007; Hiekal 2007; Ismail 2012; Hassan *et al.*, 2016; Hiekal *et al.*, 2016; Hiekal 2019 and Bhattarai *et al.*, 2020).

On the other hand, as shown in combined results (Table 8) and Fig.(4) showed that by increasing foliar nitrogen application and enhancing irrigation performance under IMP treatments, dry yield ha^{-1} increased. The maximum increments were 24.7% obtained by IMP_Cf_3 compared with control treatment ($TMP_{sf}f_0$), in which the increments showed no significant difference between the IMP_Sf_3 and IMP_Cf_2 (13.2 and 13.8%, respectively) by increasing foliar levels from 1.0 to 2.0%., also between IMP_Sf_1 and IMP_Cf_1 (4.6 and 8.0%, respectively) by foliar level 0.0%, which appear the effect of enhancing irrigation performance under IMP treatments compared with $TMP_{sf}f_0$. So, foliar spray by urea at a 1.0% level was enough to obtain satisfactory results under salinity conditions. Similar results were obtained by Hassan *et al.*, (2016) and Habiba *et al.*, (2018). These increments in dry yield may be attributed to the increases in plant growth characteristics by foliar nitrogen application rates and water distribution uniformity in the root zone along the field, with minimal losses of supplied water, consequently, the increase in moisture availability helped endorse the growth, development, and biomass yield of the pearl millet forage crop.

Table 8. Effect of management practices, water application method and foliar spray treatments on pearl millet forage yield and dry yield at 1st., 2nd. and 3rd. Cuts *(Mean values of the seasons 2014 & 2015)*

Forage yield	Treatment	1st. Cut	2nd. Cut	3rd. Cut	Mean	Sum
Fresh yield (t ha^{-1})	$TMP_{sf}f_0$	41.39^{e}	44.50^{d}	36.40^{e}	40.76^{e}	122.294^{e}
	$IMP_C f_1$	43.98^{d}	47.00^{d}	38.40^{de}	43.13^{d}	129.376^{d}
	$IMP_C f_2$	49.63^{bc}	52.16^{c}	50.40^{b}	50.73^{b}	152.196^{b}
	$IMP_C f_3$	52.82^{a}	54.16^{bc}	43.20^{c}	50.06^{b}	150.180^{b}
	$IMP_S f_1$	45.36^{d}	56.10^{ab}	40.40^{d}	47.29^{c}	141.861^{c}
	$IMP_S f_2$	48.98^{c}	58.64^{a}	45.30^{c}	50.97^{ab}	152.925^{ab}
	$IMP_S f_3$	51.41^{ab}	51.00^{c}	54.88^{a}	52.43^{a}	157.296^{a}
LSD P = 0.05		1.0316	1.6756	1.1519	0.1922	2.439
Dry yield (t ha^{-1})	$TMP_{sf}f_0$	8.96^{d}	9.82^{c}	8.01^{e}	8.93^{d}	26.787^{d}
	$IMP_C f_1$	9.62^{cd}	10.31^{bc}	9.01^{c}	9.65^{c}	28.941^{c}
	$IMP_C f_2$	10.78^{ab}	10.68^{b}	9.04^{c}	10.17^{b}	30.496^{b}
	$IMP_C f_3$	11.02^{a}	12.37^{a}	10.01^{ab}	11.13^{a}	33.402^{a}
	$IMP_S f_1$	9.06^{d}	10.49^{bc}	8.47^{d}	9.34^{c}	28.018^{c}
	$IMP_S f_2$	10.13^{bc}	13.00^{a}	10.24^{a}	11.13^{a}	33.376^{a}
	$IMP_S f_3$	10.44^{ab}	10.00^{bc}	9.89^{b}	10.11^{b}	30.327^{b}
LSD P = 0.05		0.3641	0.3385	0.1565	0.0417	0.5238

Means followed by the same small letters within columns were not significant at 5% probability level.

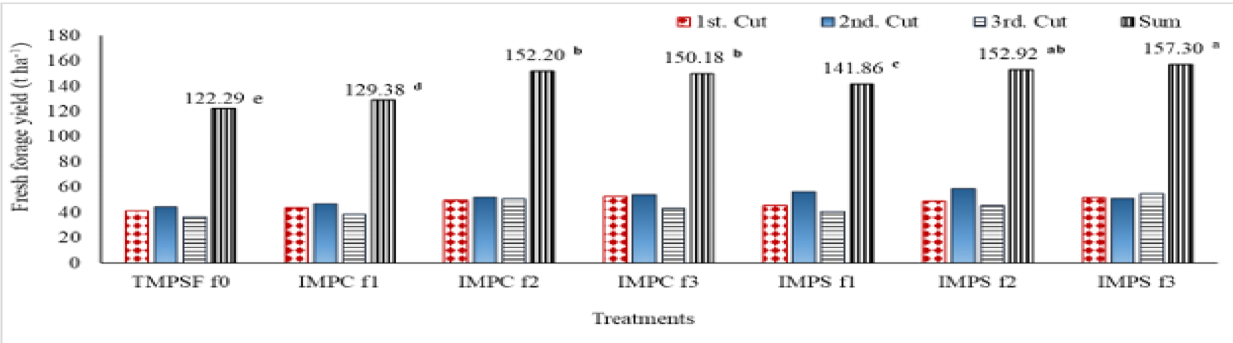

Fig. 3. Effect of management practices treatments on pearl millet fresh forage yield at 1st., 2nd. and 3rd. Cuts (Mean seasons of 2014 & 2015)

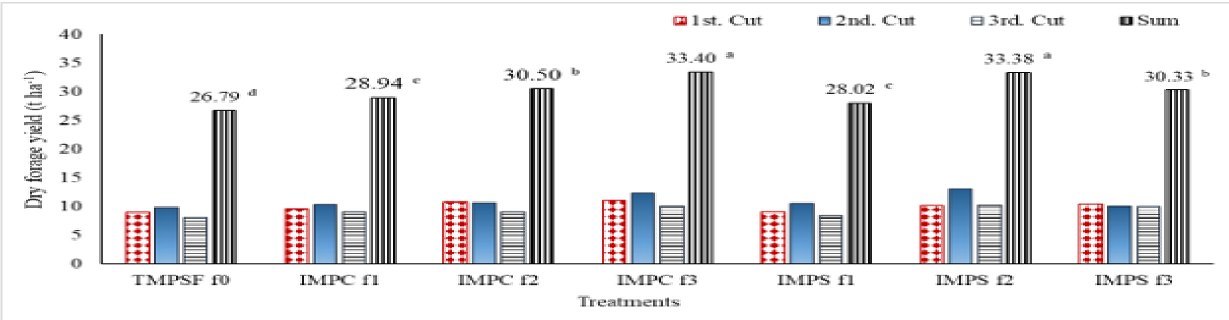

Fig. 4. Effect of management practices treatments on pearl millet dry forage yield at 1st., 2nd., and 3rd. Cuts (Mean seasons of 2014 & 2015)

Management practices methods and irrigation water use efficiency (IWUE)

Data in Fig. (5) Showed the effect of management practices treatments on irrigation water use efficiency by fresh forage yield ($IWUE_f$) at 3 cuts (Mean seasons 2014 & 2015). Results of $IWUE_f$ presented in Fig. (5) showed that the highest $IWUE_f$ was obtained from IMP_S followed by IMP_C respectively, in combined results of increasing $IWUE_f$ by foliar nitrogen application levels and enhancing irrigation performance under IMP treatments. The maximum mean value obtained was 13.26 kg m^{-3} by IMP_Sf_3 treatment, and by comparing it with $TMP_{sf}f_0$, the increments were 57.6, and 38.1% obtained by IMP_Sf_3 and IMP_Cf_3, respectively.

Meanwhile, the obtained mean values were non-significant differences between IMP_Sf_2 and IMP_Sf_3 treatments (12.89 and 13.26 kg m^{-3}, respectively) also between IMP_sf_1, IMP_Cf_2, and IMP_Cf_1 treatments (11.96, and 11.7 and 11.62 kg m^{-3}, respectively). So increasing N foliar spray, levels from 1.0 to 2.0% in both IMP_S and IMP_C treatments resulted in non-significant differences in mean values of $IWUE_f$, which clarify the combined effect of N foliar spray, enhancing irrigation performance and water uniformities under IMP treatments compared with $TMP_{sf}f_0$. These increments may be due to the increases in plant growth characteristics by water distribution uniformity in the root zone along the field with minimal losses of supplied water by deep percolation or conserve fertilizers from loss below the root zone as clarified by Reddy *et al.*, (2018).

Although IWUE has a positive correlation with yield increases, values of IWUE are almost higher under water stress conditions than under usual irrigation environments. Thus, the improvement of salt tolerance by alters some environmental factors may also greatly increase water use efficiency for plant growth and/or reduced the quantity of water required. Certainly, more work needs to be done on these relationships, Bramley *et al.,* (2013).

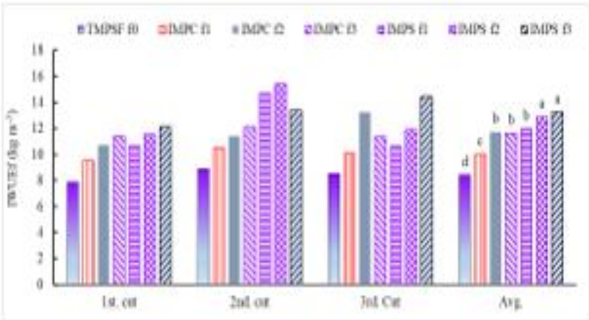

Fig. 5. Effect of management practices treatments on $IWUE_f$ by fresh forage yield each cut (Mean seasons of 2014 & 2015)

On the other side, Fig. (6) showed the effect of management practices treatments on irrigation water use efficiency by dry forage yield ($IWUE_d$) at 3 cuts (Mean seasons 2014 & 2015) in combined results of increasing $IWUE_d$ by foliar nitrogen application levels and enhancing irrigation performance under IMP treatments. The maximum mean value of 2.81 kg m^{-3} was obtained by IMP_Sf_2 treatment, and by comparing with $TMP_{sf}f_0$, the increments were 52.6 and 40.2% obtained by IMP_Sf_2 and IMP_Cf_3, respectively. Meanwhile, the obtained mean values 2.56 and 2.59 kg m^{-3} were non-significant differences between IMP_Sf_3 and IMP_Cf_3 treatments, respectively, also, it was the same value between IMP_sf_1 and IMP_Cf_2 treatments (2.36 kg m^{-3}). So N foliar spray levels were significant in both IMP_S and IMP_C treatments in $IWUE_d$ values, which clarify the combined effect of IMP treatments compared with TMP_{sf} under marginal conditions. These increments may be due to the increases in plant growth characteristics by good water distribution uniformity in the root zone along the field with minimal losses of supplied water by deep percolation and/or conserve fertilizers from loss below the root zone, Ausiku *et al.,* (2020).

Generally, increasing IWUE of IMP_S and IMP_C compared to TMP_{sf} are maybe attribute to the high obtained yield by less water applied compared to TMP_{sf} as shown in Fig (6).

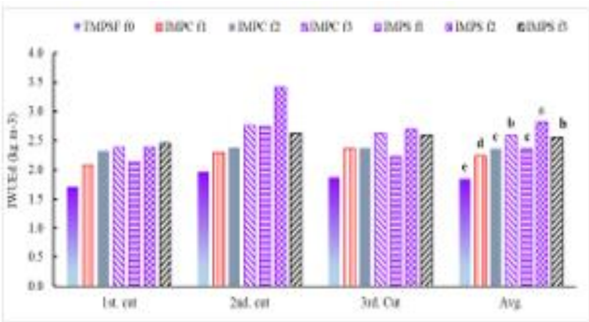

Fig. 6. Effect of management practices treatments on $IWUE_d$ by dry forage yield each cut (Mean seasons of 2014 & 2015)

CONCLUSION

The results of this study are very significant for decision-makers and farmers of marginal areas. IMP_S treatments offered the highest fresh and dry yield followed by IMP_C compared to TMP_{sf} treatments. Also, the results showed that under experiment conditions IMP_S with N foliar spray can be effectively used to capably produce fresh and dry fodder from millets with all the cuts per season under moderately saline water with salt-affected soils. Maximum IWUE value was recorded from IMP_S treatments. The challenge is to endure changing both water and soil management practices to maximize IWUE.

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حزمة الإدارة المتكاملة لتحقيق أقصى إنتاجية من علف الدخن اللؤلؤى تحت موارد التربة والمياه الهامشية في شمال سيناء – مصر

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تم إجراء تجربة حقلية في سهل الطينة بمحافظة شمال سيناء - مصر خلال موسمي الزراعة الصيفي 2014 و 2015 لدراسة تأثير حزمة الإدارة المحسنة (IMP) باستخدام طريقتين للري السطحي لإدارة تدفق المياه (التدفق المستمر IMP_C، والنبضى IMP_S) وثلاثة معاملات تسميد ورقى باليوريا "N 46 %" بتركيزات (0 ، 1.0 ، و 2.0٪) على بعض صفات النمو ومحصول العلف من الدخن اللؤلؤي (*Pennisetum glaucum LR Br*) بالمقارنة مع الإدارة التقليدية للإدارة والرى والتسميد المطبقة بمعرفة المزارع (TMP_{Sf}). أظهرت النتائج المتحصل عليها أن صفات النمو وحاصل الأعلاف في الدخن اللؤلؤي مثل ارتفاع النبات ، وعدد الأفرع م $^{-2}$ ، وحاصل الوزن الرطب والجاف كليًا زاد بشكل معنوي بواسطة IMP ، وتم الحصول لأعلى قيم معنوية لمعظم صفات النمو، ووزن العلف الطازج والجاف الكلى كمتوسط للموسمين. وفي غضون ذلك ، تأثرت صفات النمو وحاصل الأعلاف الجافة معنوياً باستخدام 2٪ من معاملة الرش الورقي باليوريا (f_3) والتي أنتجت أعلى قيم لارتفاع النبات ، وعدد الأفرع م $^{-2}$ ، وإجمالي الأوزان الرطبة والجافة هكتار $^{-1}$ مقارنة بالطريقة التقليدية لتنفيذ حزمة الإدارة ذات الخطوط القصيرة للرى (TMP_{sf}). تأثر توفير المياه بشكل كبير باستخدام تقنية التدفق النبضى لمياه الري (IMP_S). تم الحصول على أعلى قيمة لمتوسط كفاءة استخدام مياه الري من خلال إجمالي إنتاجية العلف الطازج ($IWUE_f$) بقيمة 13.26 كجم م $^{-3}$ بمعاملة IMP_Sf_3، بينما بالنسبة لإجمالي المحصول الجاف ($IWUE_d$) كانت القيمة 2.81 كجم م $^{-3}$ بمعاملة IMP_Sf_2.