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Effects of Irrigation Frequency Regimes and Weed Control Management, on Field Grown Tuberoses (*Polianthes tuberosa*, L), in the Saudi Arabian Western Region: 1. Clump Growth & Development, Bulb Yield, Water Use Efficiencies and Bulb Nutrient Contents

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MAXIMIZING subterranean tuberose clump and bulb yield. as propagule(s) for farmers and/or growers, through weed control management and rational watering frequency regimes, is thoughtful investigation, particularly under the harsh arid zone environment, in the Saudi Arabian Western Region. A Split-Split-Plot field experiment, in Randomized Complete Block Design (RCBD), with four replicates, was conducted, to investigate the effects of different irrigation frequency regimes; irrigation every 2, 4, 6 and 8 days, comprising the whole plots; manual hand weeding (unweeded control, weeding every 4, 8, and 12 weeks) representing the sub-plots; and herbicidal treatments (control, pendimethalin, glyphosate and pendimethalin plus glyphosate) allocated for the sub-sub-plots, on tuberose vegetative growth, clump growth characteristics, accompanied bulb & bulblet yield, water use efficiencies and nutrient contents in bulb tissues, during the 2001/2002 and 2002/2003 growing seasons.

Irrigating tuberose plants, frequently every two days, strongly produced plants with noticeably healthy vigorous vegetative growth, characterized by large numbers of basal leaves. These plants also developed clumps characterized by widest diameters, circumferences, heaviest weights, largest sizes, and larger numbers and weights of bulbs and/or bulblets per experimental unit, in comparison to other irrigation frequency treatments, both seasons. There were also noticeable tendency for gradual decreasing effects, in all studied traits corresponding with decreasing irrigation frequencies or lengthening watering intervals, in both seasons. Frequent irrigation every eight days considerably improved the efficiency of each single cubic meter of water consumed by tuberose plants, in producing the highest number

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or fresh weight of bulbs and/or bulblets, per sub-sub-plots, in both seasons. However, water use efficiencies, whether it was estimated based on number or on fresh weights of bulbs and/or bulblets were statistically inversely proportional to irrigation frequencies or watering intervals.

Tuberose plants subjected to frequent hand weeding every four weeks, greatly produced the largest number of basal leaves. It also produced the largest clumps, in term of diameter and/or circumference, characterized by noticeably heavier weight and larger sizes, with noticeably higher yields of bulbs & bulblets per experimental unit, and water use efficiencies, in comparison to those grown in unweeded controls or to those subjected to other weeding treatments. Nutrient content in bulb and/or bulblet's tissues were considerably reduced due to frequent hand weeding, in comparison to the untreated control, in both season.

Pendimethalin plus glyphosate immensely increased number of basal leaves, in the two growing seasons. This application also considerably increased clump diameter, circumference, weight & size, bulb and/or bulblet yields per experimental unit, water use efficiencies but greatly reduced nutrient contents in bulb tissues, in comparison to the untreated control or even to each single herbicide applied alone.

Tuberose plants grown in sub-sub-plots treated with the preemergence pendimethalin plus the postemergence glyphosate, weeded manually every four, eight and/or twelve weeks and frequently irrigated every two and/or four days showed immensely noticeable vegetative growth and underground clump and bulb yield performances, in both seasons. Therefore, these treatments are highly advisable for practical application.

Tuberose vegetative growth, expressed as number of basal leaves, had strong positive correlative relationship with clump diameter, circumference, weight, size, number and weight of bulbs and bulblets produced by experimental units. It also had considerably negative correlative relationship with water use efficiencies, based on either number or weight of bulbs & bulblets produced per experimental unit, per each cubic meter of water consumed. Furthermore, phosphorus content, in bulb tissues, in the first season, as well as potassium content, in both seasons, revealed negative correlations.

Keywords: Tuberose, Polianthes tuberosa, L., Irrigation frequency, Water regimes, Manual hand weeding, Herbicides, pendimethalin, glyphosate, Vegetative growth, Clump, bulb yield, Water use efficiency.

Aesthetically, artistically and commercially, Tuberose (*Polianthes tuberosa,* L.) is considered as one of the most an important cut flower, among almost all summer blooming flowering bulbs. It belongs to family *Agavaceae* and is native to Mexico. Its momentous importance among the commercially grown flowers is attributed to its significant potentiality for cut flower and bulb trade businesses, long vase life and essential oil industries. It is cultivated in most of the tropical and subtropical countries of the world (Asif *et al.*, 2001). Tuberose plants are mainly propagated vegetatively by bulbs, which constitute underground structures known as clumps. Tuberose clumps comprise several bulbs and/or bulblets of different sizes. These clumps are very rewarding for growers in the commercial bulb trade, since they are sold as propagating materials or propagules. It can be grown directly as it is or it can be divided, yielding several bulbs and bulblets of different sizes. A pioneer project was initiated in the western Region of Saudi Arabia aiming to improve and to maximize tuberose productivities, under the arid zone conditions (El-Naggar and Byari, 1999 a, b, c, and d). Nevertheless, further horticultural agrotechnique researches were critically required to obtain high yield with excellent commercial quality, especially under insufficiently limited water resources, mainly ground water, as well as harsh environmental condition prevailing in the Kingdom.

Irrigation with relatively high volumetric soil water content, through increasing watering frequencies or watering levels, sufficient but not excessive, was evidently proven very beneficial to almost all subterranean storing organs of flowering bulbs, for higher yield productivity, dry matter accumulations and maximum weights and sizes. Conversely, subjecting ornamental bulbs to water stress and/or water deficit resulted in immense decline and deterioration in yield and quality characteristics of underground storing organs according to researches conducted on Liatris (Stimart, 1991); Tul'p (Papanek, 1992); Bird of Paradise (Abo El Ghait, 1993); Narcissus (EL-Naggar and Nassar, 1994) and GuoMing *et al.*, 2004); Elephant Foot Yams (Santosa *et al.*, 2004); Tuberose (Nabih *et al.*, 1992; Halepyati *et al.*, 1995; Halepyati *et al.*, 2002 and Al-Moftah and Al-Humaid, 2005); Crocus (Zehan *et al.*, 2006) and Ornithogalum (El-Hanafy *et al.*, 2006).

Weed management and manipulation substantially represent a major challenge in ameliorating tuberose productivity, in the Western Region of Saudi Arabia, particularly under furrow irrigation system, which, in turns, it receptively stimulate and hasten weed growth, resulting in unfavorable and unfair weed/crop competition(s). Weed competition potentially reduces individual crop yields by 10-100 % according to Ashton & Monaco, 1991 Garcia *et al.*, 1995 and Singh *et al.*, 2002. Tuberose type of growth is, however, just similar to that growth-type of bulb crops, which was described by Hartmann *et al.*, 1981 and Ghosheh, 2004. It has poor peculiar canopy structure; small stature, shallow roots and lack of dense foliage cover with narrow upright leaves with low leaf area index. These subsequently allow weeds to successfully interfere with the crop, with poorly unfair competition, resulting in immense crop reduction. Moreover, tuberose long growing season may allow successive flushes of weeds to emerge, especially under furrow irrigation, necessitating consecutive weed control operation(s). Weeds can also harbor insects, diseases and nematodes that infest crops significantly (Ashton and Monaco, 1991 and Derr, 2004). Crop rotations, cover crops, cultivation or hoeing, soil solarization and mulching are commonly used, as horticultural agrotechniques, for weed controls

(Leroux *et al.*, 1996 and Ferguson, 2004). Mechanical weeding, cultivation, soil loosening or hoeing manipulation were traditionally practicised for many horticultural crops, particularly those developing subterranean storing organs, including ornamental bulbs; Mohanty *et al.*, 2002, found that frequent hand weeding at 30-days intervals for tuberose plants was very effective for obtaining the maximum number of leaves per clump, leaf width and length, and it greatly increased number and weights of bulbs produced per clump and also the percentage of grade I bulbs. Panwar *et al.*, 2005, also found that frequent hand weeding in field grown tuberoses immensely improved bulb growth and bulblet development. Misra and Verma (1997) reported that increasing weeding frequencies (2, 4, 5, and 8 weeding) noticeably increased gladiolus corm weight produced at the end of the flowering season. These newly produced corms, in turns, produced 2.3 – 11.7 flowers per spike at the same first season of growth. Moreover, Elephant foot yam's (*Amorphophallus spp*) vegetative growth parameters and corm growth characteristics such as yield, weight, mass and quality were also enormously improved by frequent hand weeding and hoeing (Bhaumik *et al.*, 1988; Dwibeddi & Sen, 2000 and Santosa *et al.*, 2006). Although hand weeding is generally documented, in the literature, to be very effective in controlling weeds, and also established to be very beneficial to the crop produced, it is, on the other hand, exceedingly costly, laborious and non-economical approach (Pushpalatha *et al.*, 2000), particularly in developing countries. Furthermore, during conducting and executing the operation of hand or manual weeding (weed uprooting), there were great possibilities and chances for hurting and/or disconcerting the subterranean roots and organs for such a crop. However, while hoeing and hand weeding are excellent methods for weed control, its availability and cost of labor may be prohibitive in all but the smallest production situations (Stevens *et al.*, 1993) Therefore, chemical herbicides uses and applications were compulsory indispensable as substitutes and/or auxiliary approaches, for weed control, in field grown ornamental bulbs. Mehmood *et al.*, (2007) reported that herbicides provide the most practical, effective, and economical method of weed control for increasing crop yield.

Pendimethalin {*N-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine*} is a dinitroaniline selective preemergence herbicide, which is used to control most of annual grasses and some broadleaf weeds. It principally functions throughout the inhibition of mitotic cell division and cell elongation (WSSA, 1989 and Hatzinikolaou *et al.* 2004). Many researches and investigations revealed that pendimethalin markedly improved vegetative growth as well as the underground subterranean organs' yield, weight and size of numerous flowering bulbs (Bhaumik *et al.*, 1988 on Elephant Foot Yams, Ivanova, 1999 on Iris and Bing *et al.*, 1988, Mynett and Jagusz, 1990 and Arora *et al.*, 2002 on gladioli) without any adverse effects. It also improved bulb yield and quality characteristics of subterranean organs of garlic (Khan and Imran, 2003) and onions (Jilani *et al.*, 2003, Ghaffoor, 2004, Manwat *et al.*, 2005 and Bano *et al.*, 2006). Jayakumar and Bharathi, 20C reported that 85 to 87 % of pendimethalin applied at rates up to 2 kg *a.i.* /ha, in field grown onion, was evidently dissipated by harvest time and the half life period was 12.8 – 13.2 days. Residues at harvest time (µg/g) were below detectable level. They concluded that pendimethalin is considered safe for weed management in field grown onions. Glyphosate {*N- (Phosphonomethyl) glycine* is a broad-spectrum post emergence herbicide. Its use in agriculture has expanded recently with the increase use of crops that have been genetically modified to tolerate the treatment. It is sold in the agricultural market with different trade names such as Gallup, Land master, Ranger, Roundup, Rodeo, Touchdown, Medallon and Glycel (Kidd and James, 1991; and Cox, 2004). Solinas *et al.*, 1997 reported that HPLC analysis revealed fast degradability of glyphosate in *crocus sativus's* tubers, grown in sandy and clay soils, without any phytotoxic symptoms on the crop. Glyphosate application, however, at a rate of 2 %, in field-grown tuberoses greatly enhanced number, size and weight of bulbs and bulblets according to Pal and Das, 1990; and Panwar *et al.*, 2005. On the other hand, gladiolus corms were reduced by the highest glyphosate concentration (2-8 lb/acre), although 90 % of the quack grass weed (*Agropyron repense*) was controlled by this treatment according to Ahrens, 1975.

This investigation was conducted to evaluate clump growth parameters and indices, bulb yield performances, water use efficiencies and bulb nutrient contents, of tuberose plants, as influenced by hand weeding, pendimethalin, glyphosate and their combination subjected to different watering frequency regimes, under the Western Region Arid Zone conditions of Saudi Arabia.

Material and Methods

The concurrent investigation was conducted and executed at Hada AL-Sham's Agricultural Experimental Station (HAAES), for Ornamental Plants Researches and Indoor Plant Propagation (OPRIPP), of King Abdul-Aziz University, geographically located in Hada AL-Sham's valley, North East the City of Jeddah (Makkah AL-Mokaramah vicinity), during the growing seasons of 2001/2002, 2002/2003.

- Plant Materials

Excellent quality tuberose mother clumps were imported from Egypt. Each clump included 2-3 good quality tuberose bulbs (3.5-4.5 cm in diameter). Twelve clumps yielded at least 24 cultivable bulbs, specified for each sub-sub-plot, after bulb and bulblets separation. However, the remainders of bulbs and/or bulblets were subjected to raising and breeding programs.

A Split-Split-Plot field experiment, in Randomized Complete Block Design (RCBD), in four replicates, with 1.5 x 2 meter experimental plot (experimental unit), was conducted, under different irrigation frequency regimes, to resolve these nagging problems. Irrigation frequencies (irrigation every 2, 4, 6 and 8 days) comprising the whole plots; manual hand weeding (unweeded control, weeding every 4, 8, and 12 weeks) represented the sub-plots; and herbicidal treatments (control, pendimethalin, glyphosate and pendimethalin plus glyphosate) exhibited the sub-sub-plots. Detailed materials, methods and experimental procedures, however, were documented by El-Naggar and Byari 2007 a & b.

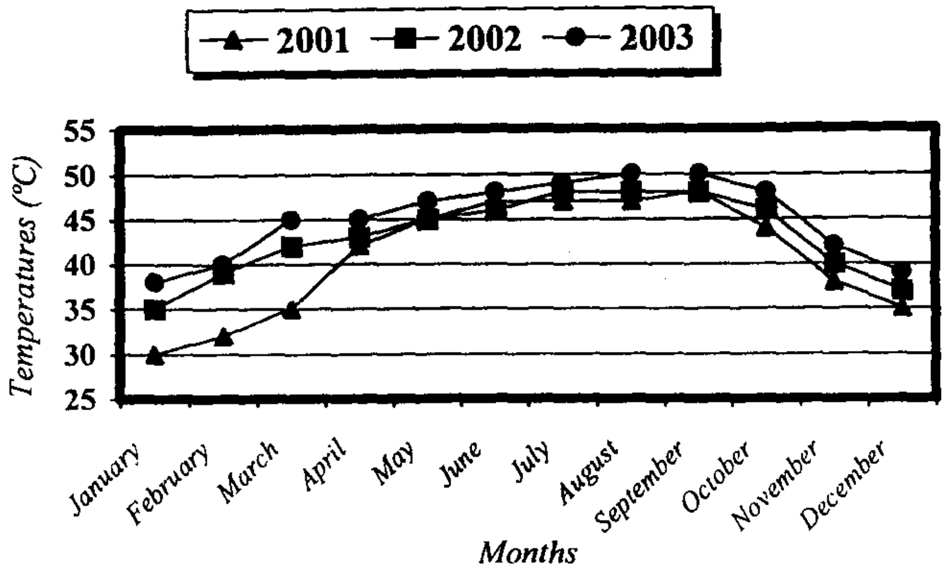

Fig.A. Maximum monthly temperatures (°C), at Hada Al-Sham's agriculture experiment station (Macca AL-Mokaramah area, KSA), over three consecutive gregorian years of 2001, 2002 and 2003.

Tuberose bulbs ranging sizes (3.5 – 4.5 cm) in diameter, and 38-55 g average weights, were subjected to planting on April 28th, 2001/2002, and April 30th in the 2002/2003, growing seasons, respectively. Bulbs were planted according to the anticipated statistical design and layout of the split-split-plot design. All experimental plots were fertilized with the 5-10-5 complete fertilizers, at the rate of 200 kg/ha, in two split doses. The first dose was given 45 days after planting, while the second one was applied after 90 days, in both seasons. Each experimental unit (sub-sub-plot) was planted with 24 tuberose bulbs (4 rows x 6 columns) of 3.5-4.5 cm in diameter, at distances of 25 x 30 cm. All experimental plots were treated with Carpofuran granules against termites (the area is colonialized with termite colonies), which dangerously attack any tender or succulent materials, in the area, such as roots, bulbs, tubers...etc.

Experimental procedures and treatments applications

Irrigation Frequencies and Watering Intervals

Four 10-ton capacity tanks were installed and devoted for the execution of this investigation, one tank per two replicates (the experiment included four replicates). These four tanks were always maintained full of available water all times for the irrigation water treatments. A-4.5 horsepower water pump was also installed to deliver water in main, sub-main, and sub-sub-main pipes and tubes, in six-bar active pressure, to the experimental plots, from these tanks. Irrigation treatments; irrigation every two, four, six and eight days were planned as to supply certain amount of water, through control points and gauges meters, calculated to reach the field capacity, for each specified experimental whole unit, assuming that the depth of the root zone distribution of tuberose plant is 30 cm depth. Each experimental whole plot in the experiment, included 16 experimental units (plots), which occupied an area of 48 m^2, required 3.00 m^3 of irrigation water, supplied by the fiberglass tanks, and were equivalent to 3000 liter/whole plot. Nevertheless, irrigation water quantities and amount, supplied through the tank suppliers and according to the measuring meter gauges readings, during the whole coarse of the investigation, were 703.00, 352.50, 235.08, and 172.87 cubic meters/whole unit on the average, which were corresponding to irrigation every two, four, six, and eight days, respectively. However, irrigational treatments and watering intervals scheduling was started after two months from the initial bulb planting. Tuberose bulbs were, however, watered, during this period, through furrow irrigation from bulb planting until complete sprouting and plant establishment took place.

Weed control treatments

Manual hand weeding and hoeing

Several farm workers performed manual hand weeding and hoeing operations, according to preplanned schedule and timetable, for the assigned sub-plots treatments; control or check (sub-plots left unweeded), sub-plots weeded every four weeks (monthly intervals), sub-plots weeded every eight weeks (bimonthly), and sub-plots weeded every twelve weeks.

Pendimethalin

Pendimethalin, (N- (1-ethylpropyl) -3,4-dimethyl-2, 6- dinitro - benzeneamine (C_{13} H_{19} N_3 O_4)), is manufactured by BASF Corporation, Agricultural Products Group, P. O. Box 13528, 26 Davis drive, Research Triangle Park, NC 27709, USA. It was bought from an agricultural establishment in Jeddah, Saudi Arabia with the trade name Pendulum® WDG (water dispersible granules), 60 % active ingredients. It was used at the rate of 2.0 kg a. i. /ha, as a dry flowable formulation (0.128 kg pendimethalin/ 10 Liter water to cover area of 384 m^2 as specified and labeled sub-sub-plots for treatments), five days after bulb planting. Pendimethalin granules were properly mixed with about 5.00 liter of water and this diluted mixture was slowly added into a Ten-liter high-pressure hand sprayer tank. However, the remainder of the tank was carefully filled with water, with continuous agitation. Nonetheless, during pendimethalin application, agitation was occasionally performed to ensure excellent mixing. Moreover, thorough agitation was also performed to resuspend the mixture before spraying is resumed, when the spray mixture was allowed to settle, during indicating the labeled specified sub-sub-plots, according to the experimental design and layout.

Glyphosate

Glyphosate, N- (Phosphonomethyl) glycine, C_3 H_8 NO_5 P, or Round up Ultra Max (60 % WSC) was used in this investigation. It is manufactured by Monsanto, Co., (800 N Lindbergh Blvd. St. Louis, Mo 63167, USA). It was used at the rate of 1.0 % a. i. /ha, in this experiment, and applied 60 days from bulb planting, as post emergence treatment, to the assigned sub-sub plots. However, dry ammonium sulphate at the rate of 2.0 % (by weight) was added to the spray solution to improve water quality of Hada Al-Sham.

Pendimethalin + Glyphosate

According to experimental design and the layout, sub-sub-plots assigned for the combined treatments of pendimethalin and glyphosate were treated with both herbicides as preemergence pendimethalin, 2 kg a. i. /ha, (5 days from planting) and round up as postemergence, 1.0 a.i % /ha, (two months from planting).

Measurements and data collection

Clump(s) and Bulb(s) Growth Parameters & Measurements

Measurements and data recording on tuberose underground materials were undertaken at the end of investigations, on October 23rd, and 25th in both seasons, respectively. Tuberose clumps were dug out, classified according to the corresponding treatment plots, packed, and transferred, through Tractors, to the greenhouses working areas. Clumps were then gently washed from any adhering soil, several times, and subjected to measurements and data recording. Measurements included average clump diameter (cm), clump circumference (cm), average clump weight (g), average clump size (cc) according to Archimedes displacement law, clump specific gravity (g/cc), yield of bulbs and bulblets produced per sub-sub-plot as numbers or as weights. Tuberose bulbs and bulblets samples were also washed gently; sliced into small pieces and backed in brown paper bags, ready for laboratory preparations and oven drying prior to chemical analysis determinations.

Chemical analyses

Samples of bulbs and bulblets representing each experimental plot were collected upon the termination of the project. In laboratory, these samples were carefully rewashed with tap water, distilled water (two times), air dried, and then subjected to oven drying at 70 °C for 48 hrs, until permanent and steady weight was attained. Dried bulbs & bulblets were grinned in a Willy mill and subjected to digestion, using the hydrogen peroxide-sulfuric acid method, according to Parkinson and Allen, 1975. Nitrogen determination followed the semi-microkjeldahl method according to Bremner and Mulvaney, 1982. Phosphorus was determined colorimetrically following the chlorostannus reduced molybdo-phosphoric blue color method in sulfuric acid system, while potassium was determined by the flame photometer, according to Jackson, 1973.

Statistical analyses

Statistical analyses were performed using the General linear Model (GLM) procedure, along with the regular analysis of variance, SAS computer package (version 8.0), and MSTAT computer Program (SAS, 1999, Steel & Torrey, 1980 and Freed *et al.*, 1985). Orthogonal polynomial regression analyses, using polynomial coefficients (Gomez and Gomez, 1984), were performed to describe response curves (linear, quadratic and cubic) of tuberose plants different traits, using the Sigma Plot Scientific Graphing System (SPSGS). However, Correlation analyses were also performed among different parameters and traits.

Results and Discussions

Effects of irrigation frequency regimes

Vegetative growth & clump growth parameters

Irrigation frequency regimes notably exhibited highly significant influencing effects, on tuberose vegetative growth and clump trait performances, in the two growing seasons (Table 1). Obviously, irrigating tuberose plants, frequently every two days, considerably produced plants with noticeably healthy vigorous vegetative growth, characterized by large numbers of basal leaves. These plants also developed clumps distinguished by widest diameters & circumferences, heaviest weights and largest sizes, in comparison to other irrigation frequency treatments, in the two growing seasons. However, these plants also produced clumps showing the lowest specific gravity. Nevertheless, it is worth noting that there were noticeable tendency for gradual decreasing effects, in all studied traits and parameters, coincide with decreasing irrigation frequencies or lengthening watering intervals, in both seasons. These performances, however, are well described and illustrated by the significant orthogonal polynomial regression analyses (Table 1 & Fig. 1). It expressed strong negative linear or quadratic responsive patterns, for vegetative growth as well as for clump growth characteristics, with high coefficient of determinations, ranging from 0.94 to 0.99, in both seasons, although clump specific gravity showed dissimilar considerable cubic responses.

The noticeable performances, of tuberose vegetative growth as well as clump growth characteristics, might be attributed to increasing watering frequencies or intensity. Irrigation with relatively high volumetric water might have increased soil water content, mineral nutrient availabilities, facilitating absorption by shallow tuberous root system of tuberose, enhancing, subsequently, plant nutritional and photosynthetic status, in comparison with comparatively less frequent irrigations. However, lowering watering frequencies or lengthening irrigation intervals might have provided tuberose plants with limited soil water content as well as nutrient availabilities, restricting its growth and development, which indirectly might have reflected on lesser photosynthates deposited in tuberose sink-storing-clumps. These results, however, are in agreement with results obtained on other different ornamental bulbs, including Liatris (Stimart, 1991); bird of baradise (Abo EL-Ghait, 1993); elephant foot yams (Santosa *et al.*, 2004); crocus (Zehan *et al.*, 2006); and Ornithogalum (EL-Hanafy *et al.*, 2006).

Tuberose bulb & bulblet yield

Bulb and bulblets produced by tuberose plants per experimental unit estimated as numbers or as weights, were considerably affected by the watering regimes and frequencies, in both seasons (Table 2). Irrigation frequency and watering every two days immensely increased number and weight of bulbs and bulblets produced by tuberose plants per sub-sub-plot, in comparison to other watering frequency treatments, in both seasons. Orthogonal polynomial regression analyses, with best curve fitting, described these performances (Fig. 2), exhibiting strong quadratic and linear patterns, in the two growing seasons, sustaining obtained results. Abundance of soil water content, provided through intensive watering frequencies every two days, might be responsible for such enhancement and high production of bulbs and/or bulblets, obtained in tuberose treated sub-sub-plots. It probably improved plant nutritional and photosynthetic status, which consequently hastened bulb growth, development and encouraged bulblet formation and development. Many investigators, however, have also reported great increment in bulb and/or bulblet's yield of numerous ornamental bulbs, due to high volumetric irrigation water provided through increasing watering intervals, including tulip (Papanek, 1992); narcissus (EL-Naggar & Nassar, 1994 and GuoMing *et al.*, 2007); tuberose (Nabih *et al.*, 1992, Halepyati *et al.*, 1995; Halepyati *et al.*, 2002 and AL-Moftah and AL-Humide, 2005) and ornithogalum (EL-Hanafy *et al.*, 2006).

Water use efficiencies

Data presented on Table 2, illustrate performances of tuberose water use efficiencies, estimated as number or unit fresh weights of bulbs and/or bulblets produced by sub-sub-plots (3 m^2) per each single cubic meter of water consumed, in both seasons. Frequent irrigation every eight days considerably improved the efficiency of each single cubic meter of water consumed by tuberose plants, in producing the highest number or fresh weight of tuberose bulbs and/or bulblets, per sub-sub-plots, in both seasons. However, water use efficiencies, whether it were estimated based on number or on fresh weights of bulbs and/or bulblets were statistically inversely proportional to irrigation frequencies or watering intervals. Subjecting tuberose plants to frequent irrigation every two days, resulted in the lowest production of tuberose bulbs and/or bulblets as numbers and/or as fresh weights, produced by each consumed single cubic meter of irrigation water per experimental unit. Orthogonal polynomial regression analyses, broken down into single degrees of freedom, with best curve fitting (Fig. 2) exhibited these performances, revealing linear, quadratic and cubic responses, with high coefficient of determinations, ranging from 0.99 to 1.00, in the two growing seasons. The poor efficiency of each single cubic meter of water, due to intensive and excessive frequent irrigation every two days, and the noticeable efficient effects of each cubic meter of water consumed, due to frequent irrigation every eight days, might probably interpreted by the marginal utility theory. Low frequent irrigation, every eight days, might have imposed relative water deficit and/or water stresses, creating hunger and/or thriftiness status, for tuberose plants. This subsequently may perhaps enforced the plants to take advantage of using each single cubic meter of water supplied very efficiently, benefiting the plants in developing more bulbs and bulblets, preserving its identity and maintaining its existences. Conversely, plant subjected to successive watering and irrigation, every two days, were undergoing extravagance, immoderate and wasteful water consumption, resulting in noticeable poor water efficiencies, left for tuberose plants. These results, however, are in agreement with results obtained by Halepyati *et al.*, 1995; and Halepyati *et al.*, 2002. EL-Naggar and Byari, 2007 a, also found that frequent irrigation every two days markedly increased tuberose competing weed's water use efficiency, based on dry weight basis, in comparison to frequent irrigation every eight days.

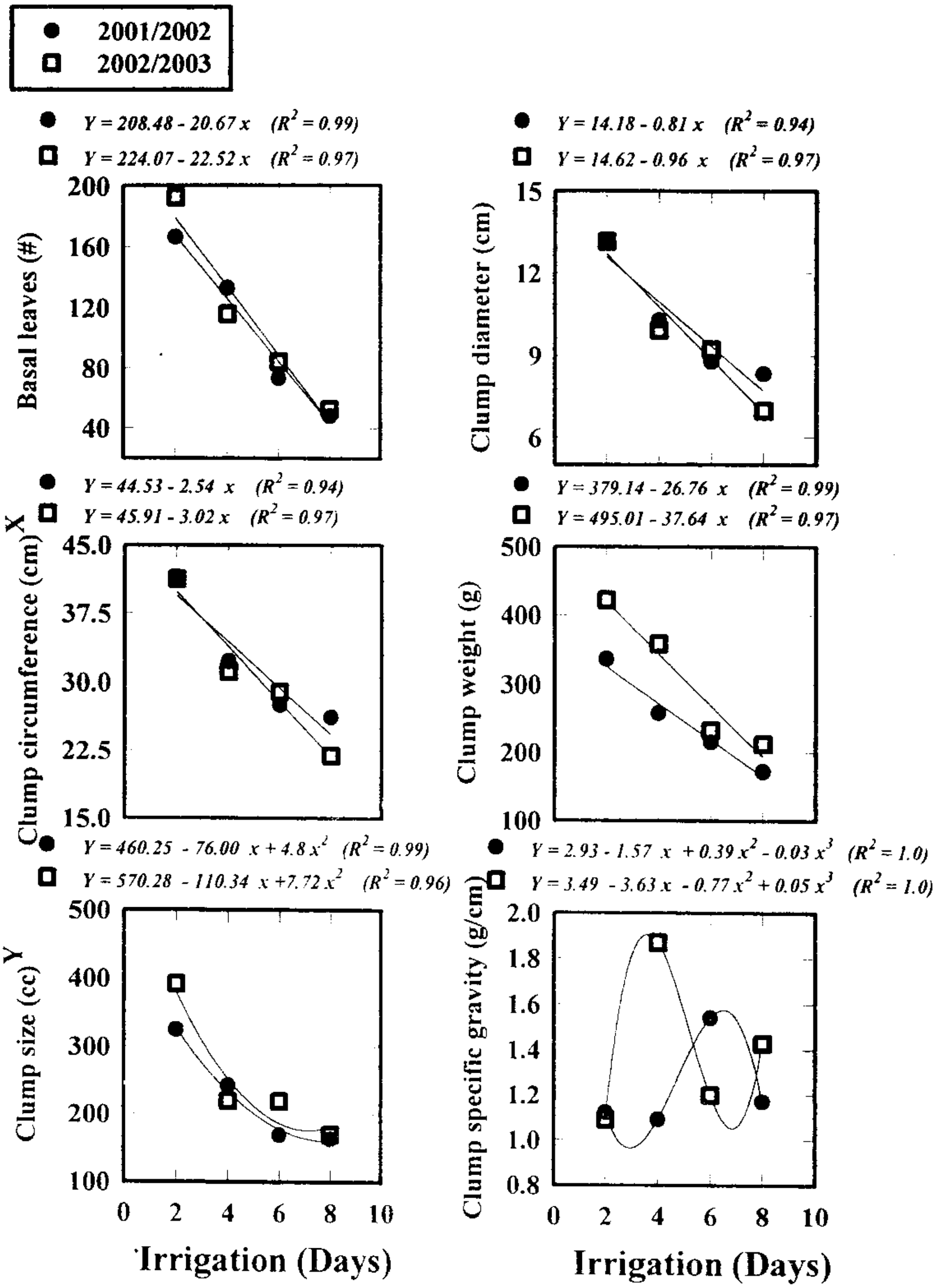

Fig.1. First (linear), second (quadratic) and third (cubic) orthogonal polynomial regression analyses response curves, with best fitting, of tuberose vegetative growth and clump growth characteristics, as functions of irrigation frequencies; predicted (solid lines) & observed (symboles).

[X] *Clump circumferen was estimated through the formula 2x 3.14 x clump diameter.*
Y Clumpsize was estimated according to the displacement law

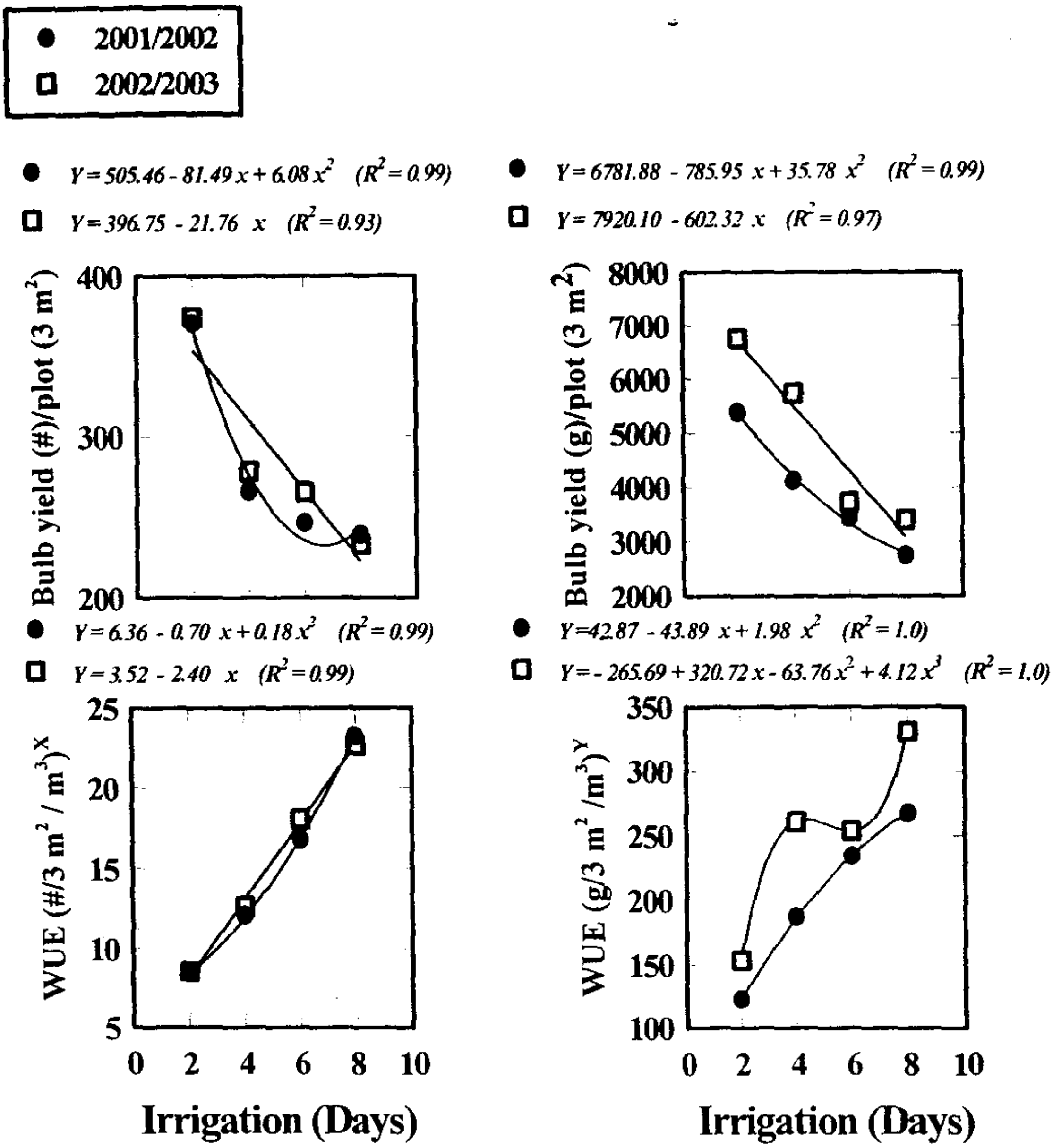

Fig.2. First (linear), second (quadratic) and third (cubic) orthogonal polynomial regression curves, with best fitting, of tuberose bulb yield and water use efficiencies, as function of irrigation frequencies; predicted (solid lines) & observed (symboles).

[X] *Water use efficiernсy was estimated as number of bulbs & bulblets produced per sub-sub- plots per each cubic meter of water consumed.*

[Y] *Water use efficiernсy was estimated as weightof bulbs & bulblets produced per sub- sub-plots per each cubic meter of water consumed.*

TABLE 1. Impacts of irrigation frequencies, hand weedings and herbicides on tuberose vegitative growth and clump growth characteristics, in field grown tuberoses (Polianthes tuberosa, L. cv. "Double"), during the 2001/02 and 2002/03 growing seasons, at Hada AL-Sham's Agricultural Experiment Station (Makkah AL-Mokaramah Area, KSA).

Growth parameters (avg.)/ clump	Basal leaves (#)		Clump diameter (cm)		Clump circumference (cm)		Clump weight (g)		Clump size (cc)		Clump specific gravity (g/cc)	
Treatments	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03
• Irrigation frequencies (Days)[Y]												
Two	166.20 a	192.68 a	13.21 a	13.15 a	41.48 a	41.28 a	336.36 a	422.10 a	324.51 a	391.50 a	1.12 b	1.09 c
Four	132.73 b	115.77 b	10.27 b	09.92 b	32.24 b	31.16 b	257.78 b	358.81 b	242.11 b	219.21 b	1.09 b	1.87 a
Six	073.45 c	084.51 c	08.76 c	09.22 b	27.50 c	28.96 b	215.02 c	233.23 c	168.44 c	219.11 b	1.54 a	1.20 bc
Eight	048.18 d	053.00 d	08.33 c	06.98 c	26.15 c	21.90 c	172.22 d	213.00 c	162.98 c	170.26 c	1.17 b	1.43 b
F-Test	**	**	**	**	**	**	**	**	**	**	*	**
LSD 0.05	11.19	13.77	1.00	1.03	3.1[illegible]	3.23	21.85	58.57	27.22	48.75	0.29	0.28
0.01	16.08	19.78	1.44	1.48	4.5[illegible]	4.64	31.39	84.15	39.11	70.03	0.42	0.40
Polynomial regression												
Linear	**	**	**	**	**	**	**	**	**	**	ns	ns
Quadratic	ns	**	**	ns	**	ns	*	ns	**	**	ns	**
Cubic	**	*	ns	*	ns	*	ns	ns	ns	**	**	**
• Manual weeding (Weeks)												
Control	086.88 d	093.59 d	08.81 d	09.03 c	27.65 d	28.35 c	194.48 c	235.81 d	187.80 d	187.45 d	1.21 a	1.47 a
Four	132.03 a	126.52 a	11.26 a	10.43 a	35.34 a	32.75 a	280.16 a	406.25 a	271.36 a	335.56 a	1.16 a	1.35 b
Eight	104.75 b	115.63 b	10.56 b	10.28 a	33.15 b	32.27 a	271.58 a	311.18 b	234.75 b	254.30 b	1.25 a	1.35 b
Twelve	096.91 bc	110.23 c	09.95 c	09.53 b	31.23 c	29.92 b	235.17 b	273.90 c	204.14 c	222.79 c	1.31 a	1.44 ab
F-Test	**	**	**	**	**	**	**	**	**	**	ns	*
LSD 0.05	5.84	4.74	0.30	0.32	0.95	1.02	19.22	14.43	16.22	10.99	—	0.12
0.01	7.83	6.36	0.41	0.43	1.28	1.36	25.78	19.35	21.75	14.74	—	—
Polynomial regression												
Linear	**	**	**	**	**	**	**	**	**	**	ns	ns
Quadratic	**	**	**	**	**	**	**	**	**	**	ns	*
Cubic	**	*	*	ns	*	ns	ns	**	**	**	ns	ns
• Herbicides												
Control	075.90 d	089.28 d	08.32 d	07.73 d	26.13 d	24.28 d	159.89 d	205.02 d	143.32 d	143.52 d	1.28 a	1.63 a
Pendimethalin	095.55 c	103.96 c	09.58 c	08.95 c	30.09 c	28.10 c	205.40 c	264.05 c	187.73 c	200.53 c	1.28 a	1.40 b
Glyphosate	116.12 b	119.84 b	10.91 b	10.26 b	34.27 b	32.22 b	266.79 b	337.65 b	233.87 b	286.34 b	1.26 a	1.38 b
Pendimethalin + Glyphosate	133.00 a	132.90 a	11.75 a	12.32 a	36.89 a	38.69 a	349.31 a	420.41 a	333.12 a	369.70 a	1.10 a	1.18 b
F-Test	**	**	**	**	**	**	**	**	**	**	ns	**
LSD 0.05	5.79	5.87	0.45	0.39	1.40	1.22	20.08	24.05	18.78	20.53	—	0.22
0.01	7.65	7.75	0.59	0.51	1.86	1.61	26.52	31.76	24.81	27.11	—	0.29
Orthogonal contrast[Y]												
Control vs Others	**	**	**	**	**	**	**	**	**	**	ns	**
Pendi. vs Pendi. + Glyphosate	**	**	**	**	**	**	**	**	**	**	ns	ns
Gly. vs Pendi. + Glyphosate	**	**	**	**	**	**	**	**	**	**	ns	*

*, **, ns *Significant, highly significant and not significant at the 0.05 and 0.01 levels of significance, according to the Least Significant Difference Test.*

[X] *Means with the same letters are not significantly different, at the 0.05 level of significance, according to The Least Significance Test.*

[Y] *Abbreviations, for orthogonal contrasts, denote; Pendi = Pendimethalin, Gly = Glyphosate and Pendi + Gly Pendimethalin + Glyphosate.*

TABLE 2. Impacts of irrigation frequencies, hand weedings and herbicides on tuberose bulb yield, water use effeiciencies and bulb nutrient content, in field grown tuberoses (Polianthes tuberosa, L. cv. "Double"), during the 2001/02 and 2002/03 growing seasons, at Hada AL-Sham's Agricultural Experiment Station (Makkah AL-Mokaramah Area, KSA).

Growth parameters (avg.)	Bulb yield/ sub-sub-plot (#)		Bulb yield/ sub-sub-plot (wt/g)		WUE (#) [Y]		WUE (wt) [Z]		Leaves N content (%)		Leaves P content (%)		Leaves K content (%)	
Treatments	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03
• Irrigation frequencies (Days)														
Two	370.42 a	374.19 a	5381.8 a	6753.6 a	08.43 d	08.52 d	122.48 d	153.70 c	2.22 a	2.25 a	2.07 a	2.03 a	2.66 a	2.64 a
Four	266.00 b	278.58 b	4124.5 b	5740.9 b	12.09 c	12.66 c	187.48 c	260.95 b	2.27 a	2.29 a	2.03 a	2.06 a	2.70 a	2.65 a
Six	246.36 b	265.63 b	3440.4 c	3731.6 c	16.77 b	18.08 b	234.20 b	254.02 b	2.29 a	2.35 a	2.10 a	2.08 a	2.70 a	2.65 a
Eight	239.28 b	233.46 b	2755.6 d	3407.9 c	23.23 a	22.67 a	267.53 a	330.87 a	2.30 a	2.35 a	2.06 a	2.03 a	2.71 a	2.71 a
F-Test	**	**	**	**	**	**	**	**	ns	ns	ns	ns	ns	ns
LSD 0.05	30.07	58.20	349.60	937.17	2.07	3.50	19.66	46.51	—	—	—	—	—	—
0.01	43.20	83.61	502.24	1346.3	2.97	5.03	28.24	66.81	—	—	—	—	—	—
Polynomial regression														
Linear	**	**	**	**	**	**	**	**	ns	ns	ns	ns	ns	ns
Quadratic	**	ns	*	ns	*	ns	*	ns	ns	ns	ns	ns	ns	ns
Cubic	ns	ns	ns	ns	ns	ns	ns	**	ns	ns	ns	ns	ns	ns
• Manual weeding (Weeks)														
Control	252.96 c	231.04 d	3111.7 c	3772.9 d	13.66 c	12.63 c	160.86 c	202.76 d	2.36 a	2.44 a	2.20 a	2.16 a	2.81 a	2.77 a
Four	315.05 a	341.08 a	4482.5 a	6500.0 a	16.84 a	18.05 a	236.73 a	311.53 a	2.19 b	2.22 b	1.88 b	1.95 a	2.59 b	2.55 c
Eight	284.67 b	298.66 b	4345.2 a	4978.8 b	15.32 b	15.99 b	217.70 a	249.08 b	2.23 ab	2.27 b	2.03 ab	2.00 a	2.66 b	2.65 bc
Twelve	269.39 bc	281.10 c	3762.7 b	4382.3 c	14.71 bc	15.25 b	196.40 b	225.17 c	2.31 ab	2.31 b	2.15 a	2.08 a	2.71 ab	2.69 ab
F-Test	**	**	**	**	**	**	**	**	*	**	*	ns	**	**
LSD 0.05	17.90	13.81	307.55	230.88	1.31	0.76	20.15	11.53	0.15	0.12	0.24	—	0.12	0.11
0.01	24.00	18.52	412.39	309.59	1.76	1.01	27.05	15.86	0.21	0.16	0.33	—	0.16	0.14
Polynomial regression														
Linear	**	**	**	**	**	**	**	*	ns	*	ns	ns	*	*
Quadratic	**	**	**	**	**	**	**	**	*	**	**	ns	**	**
Cubic	**	**	ns	**	ns	**	ns	**	ns	ns	*	ns	ns	ns
• Herbicides														
Control	203.49 d	201.46 d	2558.2 d	3280.3 d	10.77 d	10.87 d	131.91 d	163.71 d	2.49 a	2.53 a	2.44 a	2.30 a	2.90 a	2.84 a
Pendimethalin	253.82 c	260.52 c	3286.4 c	4224.8 c	13.85 c	14.11 c	169.19 c	220.47 c	2.32 b	2.34 b	2.16 b	2.14 ab	2.75 b	2.72 b
Glyphosate	297.00 b	315.16 b	4268.7 b	5402.4 b	16.22 b	16.83 b	224.95 b	270.55 b	2.22 b	2.23 bc	1.97 b	1.98 b	2.65 b	2.63 b
Pendimethalin + Glyphosate	367.76 a	374.73 a	5588.9 a	6726.5 a	19.68 a	20.12 a	285.67 a	342.81 a	2.05 c	2.14 c	1.69 c	1.77 c	2.47 c	2.46 c
F-Test	**	**	**	**	**	**	**	**	**	**	**	**	**	**
LSD 0.05	21.90	24.87	321.27	384.83	1.38	1.35	17.30	18.71	0.14	0.12	0.22	0.17	0.13	0.10
0.01	28.93	32.84	424.30	508.23	1.82	1.79	22.84	24.70	0.18	0.16	0.29	0.23	0.17	0.13
Orthogonal contrast [Q]														
Control vs Others	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Pendi. vs Pendi. + Glyphosate	**	**	**	**	**	**	**	**	**	ns	**	**	**	**
Gly. vs Pendi. + Glyphosate	**	**	**	**	**	**	**	**	**	**	**	**	**	**

*, **, ns Significant, Highly significant and not significant at the 0.05 & 0.01 levels of Significance, According to the Least Significant Difference Test

[X] Means with the Same Letters are not Significantly Different, at the 0.05 Level of Significance, According To The L.S.D Test of Significance

[Y & Z] Water Use Efficiencies, Estimated as Number of Bulbs & Bulblets Produced or Estimated as Unit fresh weight of Bulbs / Sub-Sub-Plot (3 m^2) / Each Single Cubic Meter of Water Consumed.

[Q] Abbreviations, for orthogonal contrasts, denote, Pendi = Pendimethalin, Gly = Glyphosate and Pendi + Gly = Pendimethalin + Glyphosate.

Nutrient content in bulb & bulblet tissues

Statistical analyses revealed no significant differences were detected for N, P, and K contents, in tuberose bulb and/or bulblet tissues, due to the different irrigation frequency regimes, in both seasons.

Effects of manual hand weeding

Vegetative growth & clump growth parameters

The impacts of the different manual weeding treatments, on tuberose vegetative growth and clump characteristic traits were depicted on Table 1. Obviously, tuberose plants subjected to frequent hand weeding every four weeks, immensely produced the greatest number of basal leaves. It also produced the largest clumps, in term of diameter and/or circumference, characterized by noticeably heaviest weight and largest sizes, in comparison to those grown in unweeded controls or to those subjected to other weeding treatments. However, although hand weeding every eight and/or twelve week treatments were considerably effective, in improving vegetative growth as well as clump growth parameters, comparable to the untreated controls, they were statistically less effective or equally effective, in some cases, in comparison to frequent weeding every four weeks. These performances are well described & illustrate through the orthogonal polynomial regression analyses, broken down into single degree of freedom (Table 1 & Fig.3). These polynomials, with best curve fitting, yielded strong positive quadratic and/or cubic responses, with high coefficient of determinations (R^2 = 0.98 to 1.0), with the exception of clump specific gravity. The favorable impacts of manual hand weeding, in general, particularly weeding every four weeks might be attributed chiefly to strong impacts on hindering and hampering weed competition and weed removal, which subsequently might have benefited tuberose plants, due to providing more available soil water moisture, more minerals and nutrients, spaces and more ambient solar energy, which were otherwise would have been utilized by the interfered competent weeds. However, EL-Naggar and Byari (2007 a) found that weeding every four and/ or eight weeks greatly reduced weed population density, fresh and dry weights, weed water use efficiencies and considerably increased weed control efficiency, compared to the unweeded control, in the two growing seasons. Moreover, results of Mohanty *et al.,* 2002; and Panwar *et al.,* 2005 on tuberose; Misra and Verma, 1997, on gladiolus; and Bhaumik *et al.,* 1988, Dwibeddi & Sen, 2000 and Santosa *et al.,* 2006 on elephant foot yams, are on the same line, sustaining the preceding obtained results.

Tuberose bulb & bulblet yield

Manual hand weeding substantially affected tuberose bulbs and/or bulblets yield, whether it was estimated as number or as fresh weight, produced by sub-sub-plots, in both seasons (Table 2). Frequent hand weeding, every four weeks considerably increased tuberose bulb and/or bulblet number produced by experimental units. It also increased its fresh weights, in comparison to the unweeded controls. Nevertheless, reducing or eliminating weed competions, may perhaps be responsible for such improvement and increases in tuberose bulbs and noticeable encouragement of bulblet formation. Mohanty *et al.,* 2002 and Panwar *et al.,* 2005, also obtained similar results, due to frequent weeding, in field grown tuberoses.

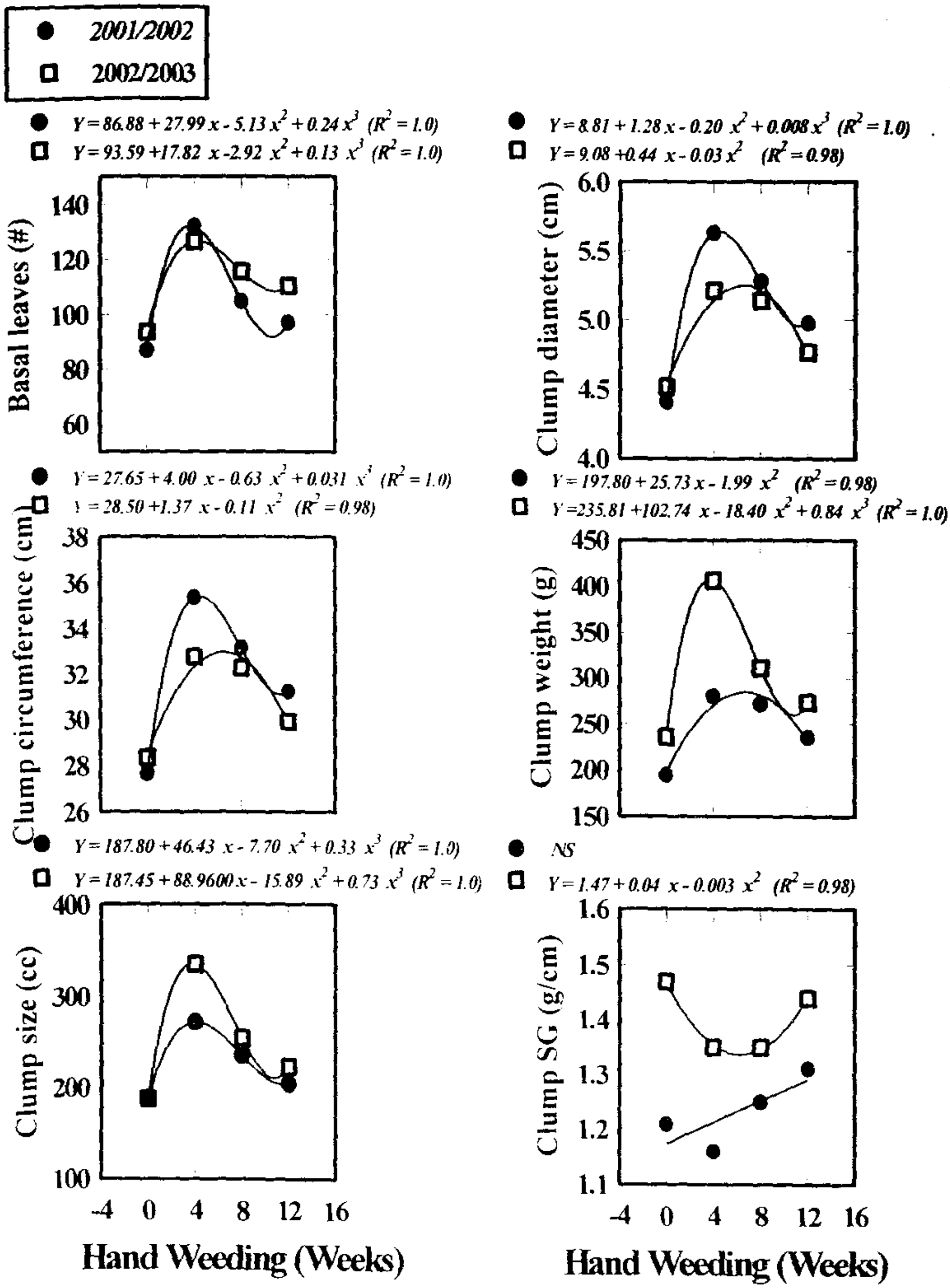

Fig.3. Second (quadratic) and third (cubic) orthogonal polynomial regression analyses response curves, with best fitting, of tuberose vegetative growth and clump growth characteristics, as functions of manual hand weedind ; predicted (solid lines) & observed (symboles).

Water use efficiencies

Manual hand weeding expressed strong impacts on tuberose water use efficiencies, estimated as number or fresh weights of bulb and/or bulblets produced by sub-sub-plot per each cubic meter of water consumed, in the two growing seasons (Table 2). Data analyses revealed noticeable superiority of frequent hand weeding every four weeks over unweeded controls or even over other weeding treatments, in considerably increasing water use efficiencies, in both seasons. Figure 4; exhibit this superiority through either quadratic or cubic responses (R^2 = 0.84 to 1.0), as a result of orthogonal polynomial regression analyses, with best curve fitting. High efficiency of each single cubic meter of irrigation water consumed and its superiority over that in unweeded controls or those consumed in other weeded treatments, might be due strong impacts of weeding every four weeks in reducing weed/tuberose competition, achieved by immensely reducing weed density as well as weed-water-use efficiencies, based on number of emerged weeds or unit dry weight, as reported by EL-Naggar and Byari, 2007 a. Hence, efficiency of consumed irrigation water, for the competing tuberose was obviously high and noticeably & efficiently superior. This consequently might have been reflected on considerable bulb and bulblet yield.

Nutrient content in bulb & bulblet tissues

Table 2, demonstrate that nitrogen, phosphorus and potassium contents, in tuberose bulb & bulblet's tissues, as influenced by the different hand weeding treatments. Evidently, nutrient content in bulb and/or bulblet's tissues were considerably reduced due to frequent hand weeding, in comparison to the untreated controls, in both seasons, although phosphorus content showed no statistical differences, only in the second season. These performances are also depicted on Fig. 4, exhibiting either negative quadratic or cubic responses (R^2 = 0.84 to 1.0), as a result of breaking down the three degrees of freedom, for hand weeding treatments, into single ones, via orthogonal polynomial regression analyses, with best curve fitting. Low percentages of N, P and K in tuberose bulb and/or bulblet's tissues, in comparison to those of the untreated control, due to hand weeding treatments, in general, and frequent hand weeding every four weeks in particular, might be attributed mainly to the dilution effects, resulted from considerably higher yields in bulb & bulblet's numbers and also in weights.

Effects of herbicidal treatments

Vegetative growth & clump growth parameters

Tuberose vegetative growth, represented by number of basal leaves produced per plant, as well as clump growth characteristics traits were profoundly influenced by the different herbicidal treatments (Table 1). Obviously, pendimethalin plus glyphosate immensely increased number of tuberose basal leaves, in the two growing seasons. This application also considerably increased clump diameter, circumference, weight and size, in comparison to the untreated control or even to each single herbicide applied alone. However, pendimethalin or glyphosate applications, as single treatment, were also significantly effective, in improving vegetative growth and clump growth parameters, in both seasons, when compared to untreated control or even when compared to each other. The orthogonal contrast, as an efficient mean comparison in this case, breaking down the three degrees of freedom into single ones, to identify main reason(s) responsible for such highly significant considerable effects of herbicides, revealed highly significant impact, for all possible ways of comparisons. This statistically conferred that; there were powerful synergism of pendimethalin and glyphosate, when they applied together as preemergence and postemergence herbicides. These herbicides timing of application functionally add up and synergistically encourage each other in controlling emerged weeds efficiently. EL-Naggar and Byari (2007 a) found that the existence of pendimethalin and glyphosate together remarkably reduced weed density, fresh and dry weights and considerably increased weed control efficiency, in field-grown tuberoses. Additionally, pendimethalin was also reported as an effective weed control herbicide, improving vegetative growth and subterranean storing organs of several ornamental bulbs, including elephant foot yam (Bhaumik *et al.*, 1988); iris (Ivanova, 1999); gladioli (Bing *et al.*, 1988; Mynett & Jagusz, 1990 and Arora *et al.*, 2002) and tuberose (Panwar *et al.*, 2005; and EL-Naggar & Byari 2007 a , b). Moreover, glyphosate, on the other hand, was found effective in improving bulb growth characters of tuberose according to Pal and Das 1990; and Panwar *et al.*, 2005.

Tuberose bulb & bulblet yield

Data presented in Table 2, clearly demonstrate tuberose bulb & bulblet yield performances, whether it was estimated as numbers or as fresh weights produced by experimental units, in the two growing seasons, as influenced by the different herbicidal treatments. Apparently, sub-sub-plots treated with the preemergence pendimethalin and the postemergence glyphosate produced the highest number and weight of bulb and/or bulblets, in comparison to the untreated controls or even when compared to either applied herbicide, in both seasons. Orthogonal contrast, revealed strong synergistic effects of both herbicides. This evidently might have indirect responsibility in improving tuberose underground storing organs, through efficient weed control, according to findings of EL-Naggar and Byari 2007 a & b, minimizing and/or alleviating weed competitions, in favor of benefiting tuberose bulb yield. However, Mehmood *et al.*, (2007) also reported that herbicides provide the most practical, effective and economical method of weed control for increasing crop yield. Although bulb yield was improved, due to either applied herbicide, in tuberose, as an ornamental flowering bulb, garlic and onion bulb yields and cloves, on the other side, as non-flowering subterranean bulbs, were immensely increased by herbicidal weed control, without any apparent adverse effects, according to Khan & Imran, 2003, Jilani *et al.*, 2003, Ghaffoor, 2004; Manwat *et al.*, 2005 and Bano *et al.*, 2006.

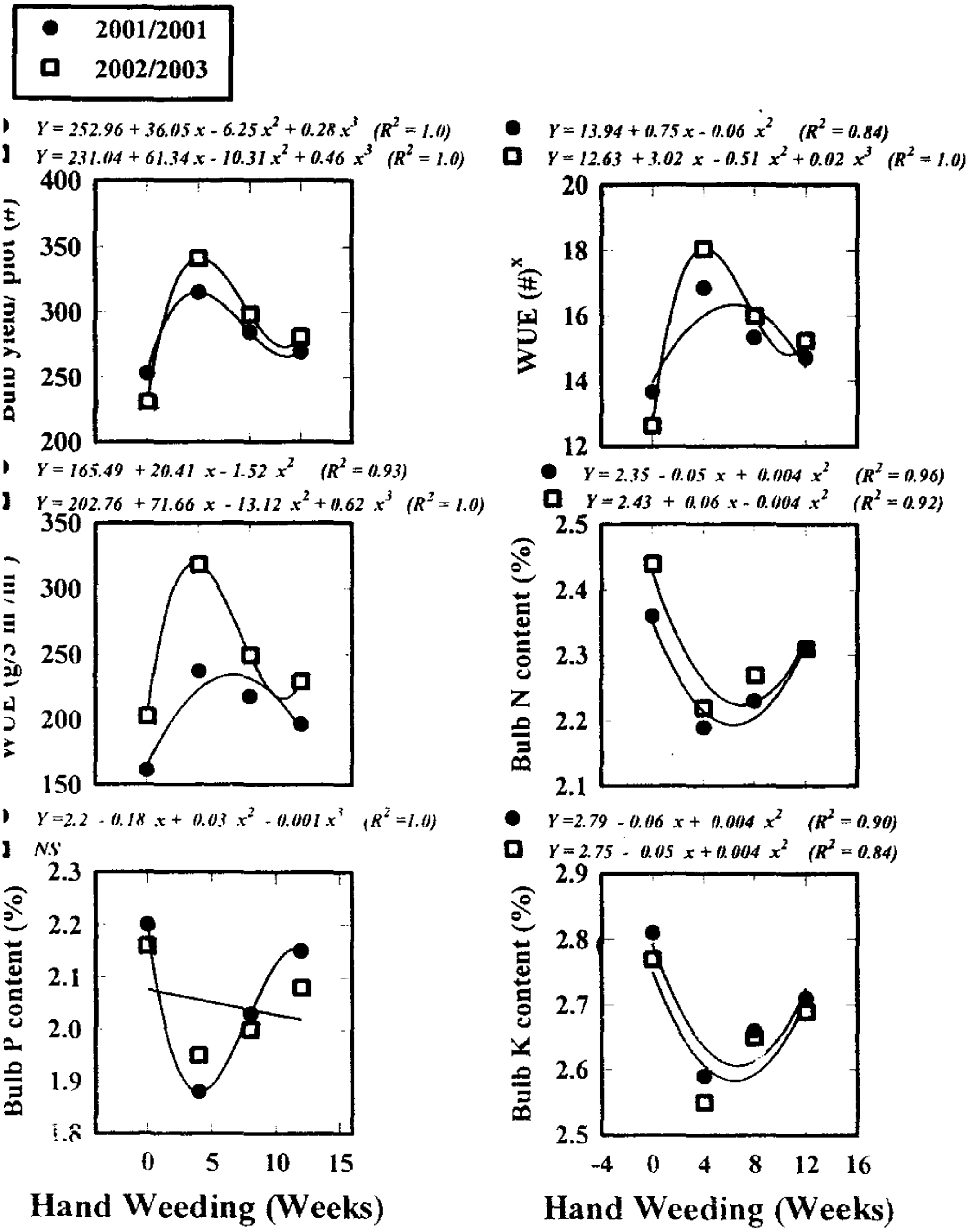

Fig.4. Second (quadratic) and third (cubic) orthogonal polynomial regression analyses response Curves, with best fitting, of tuberose bulb yield, water use efficiencies and bulb nutrient content, as functions of manual hand weedind ; predicted (solid lines) & observed (symboles).

[X] Water use efficierncy was estimated as number of bulbs & bulblets produced per sub-sub- plots per each cubic meter of water consumed.

[Y] Water use efficierncy was estimated as weightof bulbs & bulblets produced per sub- sub-plots per each cubic meter of water consumed.

Water use efficiencies

Pertaining to efficiency of irrigation water, in field grown tuberoses, each single cubic meter of water consumed, during irrigating sub-sub-plots receiving pendimethalin plus glyphosate, was substantially capable of producing efficiently the highest number and/or weight of bulb and/or bulblets, in comparison to the untreated control or even to any applied herbicide, in both seasons (Table 2). The favorable water use efficiencies, whether the estimation was depending on number or on fresh weight of bulbs and bulblets produced by sub-sub-plots per each cubic meter of water consumed, might perhaps be attributed indirectly to efficient weed control, with reference to pendimethalin plus glyphosate, as preemergence and postemergence herbicides. This strong and noticeable weed control, minimized weed competitions for irrigating water as well as for nutrients and solar energy and spaces, markedly reduced weed-water use efficiencies and enhanced at the same time water use efficiency of irrigation water, which in turn was in favor of tuberose crop bulb yield. EL-Naggar and Byari (2007 a & b), obtained results, on weed control and water use efficiencies, agreeably supporting obtained results.

Nutrient content in bulb & bulblet tissues

Nitrogen, phosphorus and potassium contents, in tuberose bulb & bulblet's tissues, as influenced by the different herbicidal treatments, during the two growing seasons, are presented in Table 2. Statistical analyses of the obtained data clearly indicated that untreated controls showed the highest contents of N, P and K, in tuberose bulb tissues, in both seasons. However, bulb tissues, obtained from pendimethalin plus glyphosate treated sub-sub-plots exhibited the lowest N, P and K contents, in both seasons. Obviously, either pendimethalin or glyphosate, when applied separately, showed considerably less nutrient content percentages, when compared to the untreated controls and noticeably higher than those percentages of pendimethalin plus glyphosate treated sub-sub-plots. The immense reduction in N, P and K percentages, in tuberose bulb tissues, might be, primarily, attributed to considerably high production of bulbs and/or bulblets, in terms of numbers and/or weights. This subsequently resulted in obvious dilution effects, to take place.

Impacts of mutual interactive effects

Irrigation frequency regimes, manual hand weeding and the different herbicidal treatments, as main investigated factors, interacted mutually together resulting in highly significant, significant and non-significant second and/or third order4 effects, for tuberose vegetative growth, clump growth traits and parameters as well as bulb yield produced per sub-sub-plot, in the two growing seasons (Tables 3 & 4). The third order interactive effects, however, is commonly meaningful, drawing the whole picture of the three investigated factors, when they co-existed together, although the tendency to be avoided sometimes, for hard and complex interpretation. Nonetheless, this manuscript may only focus on discussing the third order interactive effects.

TABLE 3. Mutual interactive effects of irrigation frequencies, hand weeding, and herbicides on tuberose vegitative growth, and clump growth characteristics, in field grown tuberoses (Polianthes tuberosa, L. cv. "Double"), during the 2001/02 and 2002/03 growing seasons, at Hada AL-Sham's Agricultural Experiment Station (Makkah AL-Mokaramah Area, KSA).

Growth parameters (avg.)/ clump	Basal leaves (#)		Clump diameter (cm)		Clump circumference (cm)		Clump weight (g)		Clump size (cc)		Clump specific gravity (cm)	
Interactions	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03
Irrigation x Weeding	**	**	**	ns	**	ns	**	**	*	**	ns	ns
Irrigation x Herbicides	**	**	*	**	*	**	**	**	**	**	*	ns
Weeding x Herbicides	ns	**	ns	**	ns	**	**	**	**	**	*	ns
Irrigation x Weeding x Herbicides	**	**	**	**	**	**	**	**	**	**	*	ns

*, **, ns *Significant, highly significant and not significant at the 0.05 & 0.01 levels of significance, according to the Least Significance Difference Test.*

TABLE 4. Mutual interactive effects of irrigation frequencies, hand weeding, and herbicides on tuberose bulb yield, water use efficiencies and bulb nutrient content, in field grown tuberoses (Polianthes tuberosa, L. cv. "Double"), during the 2001/02 and 2002/03 growing seasons, at Hada AL-Sham's Agricultural Experiment Station (Makkah AL-Mokaramah Area, KSA).

Bulb Characteristics (avg)/sub-sub-plot ($3m^2$)	Bulb Yield (#)		Bulb Yield (wt)		WUE (#) [X]		WUE (WT) [Y]		Bulb N content (%)		Bulb P content (%)		Bulb K content (%)	
Interactions	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2002/03	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2002/03
Irrigation x Weeding	ns	**	**	**	ns	**	ns	**	ns	ns	ns	ns	ns	ns
Irrigation x Herbicides	ns	**	**	**	**	**	**	**	ns	ns	ns	ns	ns	ns
Weeding x Herbicides	ns	**	**	**	ns	**	**	*	ns	ns	ns	ns	ns	ns
Irrigation x Weeding x Herbicides	*	ns	**	**	ns	ns	**	ns	ns	ns	ns	ns	ns	ns

*, **, ns *Significant, highly significant and not significant at the 0.05 & 0.01 levels of significance, according to the Least Significance Difference Test.*

[X] *Water use efficiency was estimated as number of bulbs & bulblets produced / sub-sub-plot ($3m^2$) / cubic meter of water consumed.*

[Y] *Water use efficiency was estimated as weight of bulbs & bulblets produced / sub-sub-plot ($3m^2$) / cubic meter of water consumed.*

Irrigation frequency regimes x manual hand weeding x herbicidal treatments

Performances of tuberose vegetative growth (number of basal leaves), clump growth characteristics and traits as influenced by the three investigated factors, when they reciprocally and mutually interacted together, are depicted in Harvard's Figures 5 & 6. Tuberose plants grown in sub-sub-plots treated with the preemergence pendimethalin plus the postemergence glyphosate, weeded manually every four, eight and/or twelve weeks and frequently irrigated every two and/or four days showed immensely noticeable vegetative growth and underground clump and bulb yield performances, in both seasons. It considerably produced large numbers of basal leaves, wide and heavy clumps with big sizes, developing bulbs and/or bulblets of heavy weights. On the other hand, plant grown in sub-sub-plots, non-herbicidally treated at all (controls), non-weeded at all (controls) and subjected to frequent irrigation every eight or even six days exhibited contrasting effects. However, vigorous vegetative growth, large and heavy clumps full of bulbs and/or bulblets produced by tuberose plants, in such specific sub-sub-plots, may be attributed to the mutual interactive impacts of the three factors, when they co-existed together. In a previous study, on weed control in field grown tuberoses, EL-Naggar and Byari (2007 b), found that pendimethalin plus glyphosate at any level of hand weeding, along with frequent irrigation every two and/or four days strongly reduced weed population density, fresh and dry weights, considerably increased weed control efficiency and markedly minimized weed-water-use-efficiencies, in both seasons. Accordingly, highly efficient weed control accompanied with minimal weed-water-use-efficiencies, avoiding any probable weed interference or competition, might be accountable for such noticeable performances for tuberose basal leaves and clump development. In contrast, lack of weed control, along with low levels of irrigation and water stress might be responsible for such adverse performance(s).

Pearson correlation analyses

Pearson correlation analytical matrix, among all studied traits and parameters, with correlation coefficients, in the two growing seasons, are presented on Table 5. Tuberose vegetative growth, expressed as number of basal leaves, had strong positive correlative relationship with clump diameter, circumference, weight, size, number and weight of bulbs and bulblets produced by experimental units. It also had considerably negative correlative relationship with water use efficiencies, based on either number or weight of bulbs & bulblets produced per experimental unit, per each cubic meter of water consumed. Furthermore, phosphorus content, in bulb tissues, in the first season, as well as potassium content, in both seasons, revealed negative correlations. Inferences deduced, from correlated matrix, implied that as number of basal leaves markedly increased, as function of efficient weed control, particularly under excessively abundance of irrigation water, photosynthetic activities as well as metabolic photosynthates would accordingly increased, migrating to the underground storing sink. Subsequently, clump vigor, diameter and circumference, weight and size as well as bulb & bulblet yields would also increased accordingly. Nevertheless, efficient weed control and excessively abundance of watering, while it improved vegetative growth, it reduced the efficiency of each single cubic meter of water consumed in producing bulbs and/or bulblets, at the same time, due to profligate and/or exorbitant water consumption, resulting in such negative correlative relationships. Besides, the negative correlative relationship between vegetative growth and nutrient content, in bulb tissues, might be attributed to immense diluting effects.

Bulb yield produced per experimental unit, estimated as number of bulbs & bulblets were strongly correlated positively with bulb yield estimated as weight, water use efficiencies, estimated as number or unit fresh weight of bulbs and/or bulblets produced/experimental unit, and negatively correlated with phosphorus and potassium content, in bulb tissues. These relationships are perhaps essentially due to cause and effect functions; as the efficiency of each single cubic meter of water increases, bulb yield produced by sub-sub-plots would increase accordingly. However, increases in bulb yield produced, expressed, as numbers, would result in decrease in nutrient content, in bulb tissues.

It is worthwhile noting that water use efficiencies, based on either number and/or as weight of bulbs & bulblets, were significantly and negatively correlated with phosphorus and potassium contents, in bulb tissues. Obviously, as water use efficiencies increases, tuberose bulb yield as number and/or as weight would also increase correspondingly, resulting in internally endogenous dilutions of both phosphorus and potassium, in bulb tissues.

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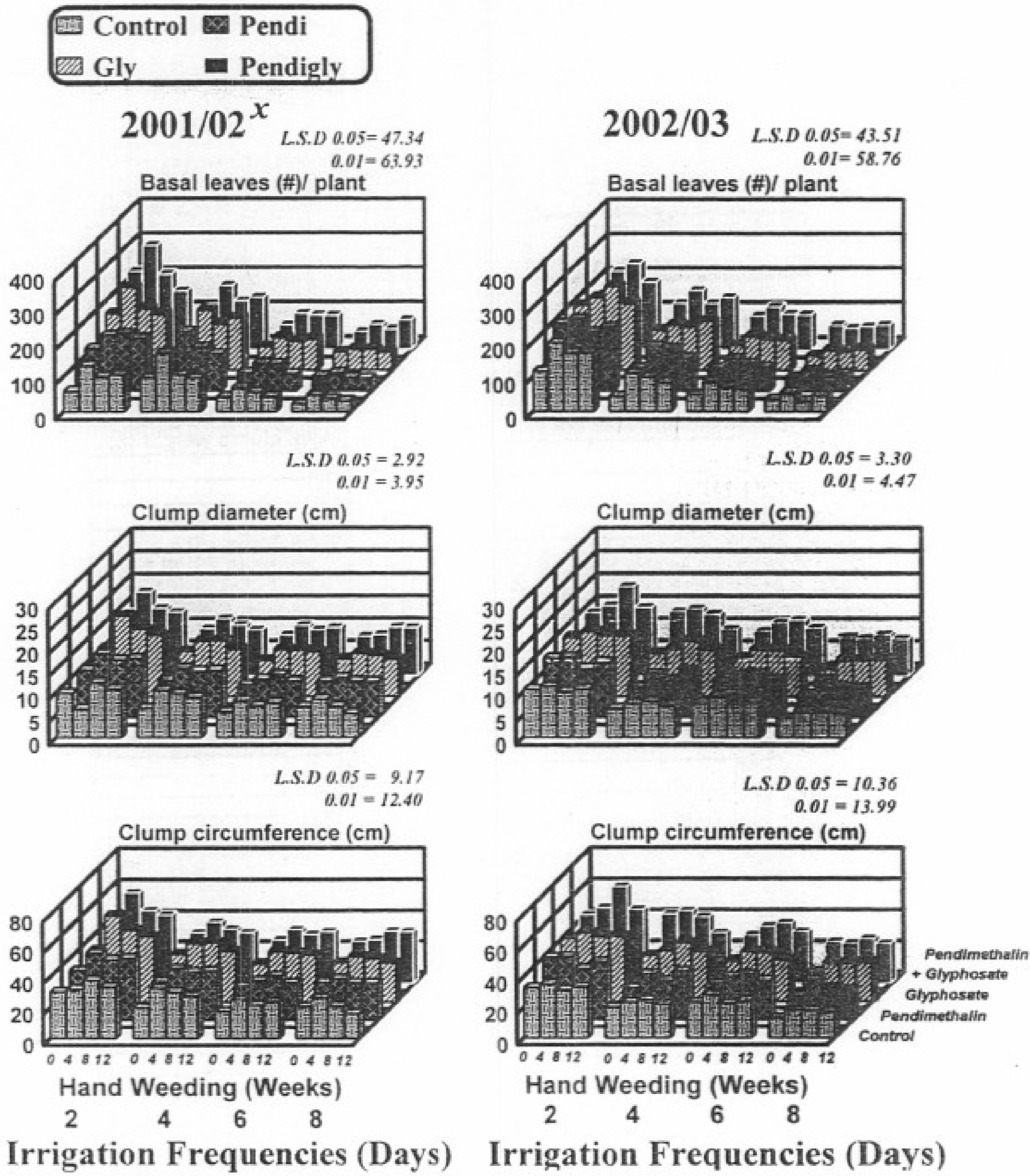

Fig.5. Tuberose number of basal leaves/ plant, average clump diameters and circumferences, as influenced by the mutual interactive effects of irrigation frequencies, manual hand weeding and herbicides, during the 2001/02 and 2002/03 growing seasons, at Hada AL-Sham's Agricultural Experiment Station (Makkah AL-Mokaramah Area, KSA).

[x] *Abbreviations, of treatments, in the series denote; Pendi + Pendimethalin, Gly = Glyphosate and Pendigly = Pendimethalin + Glyphosate.*

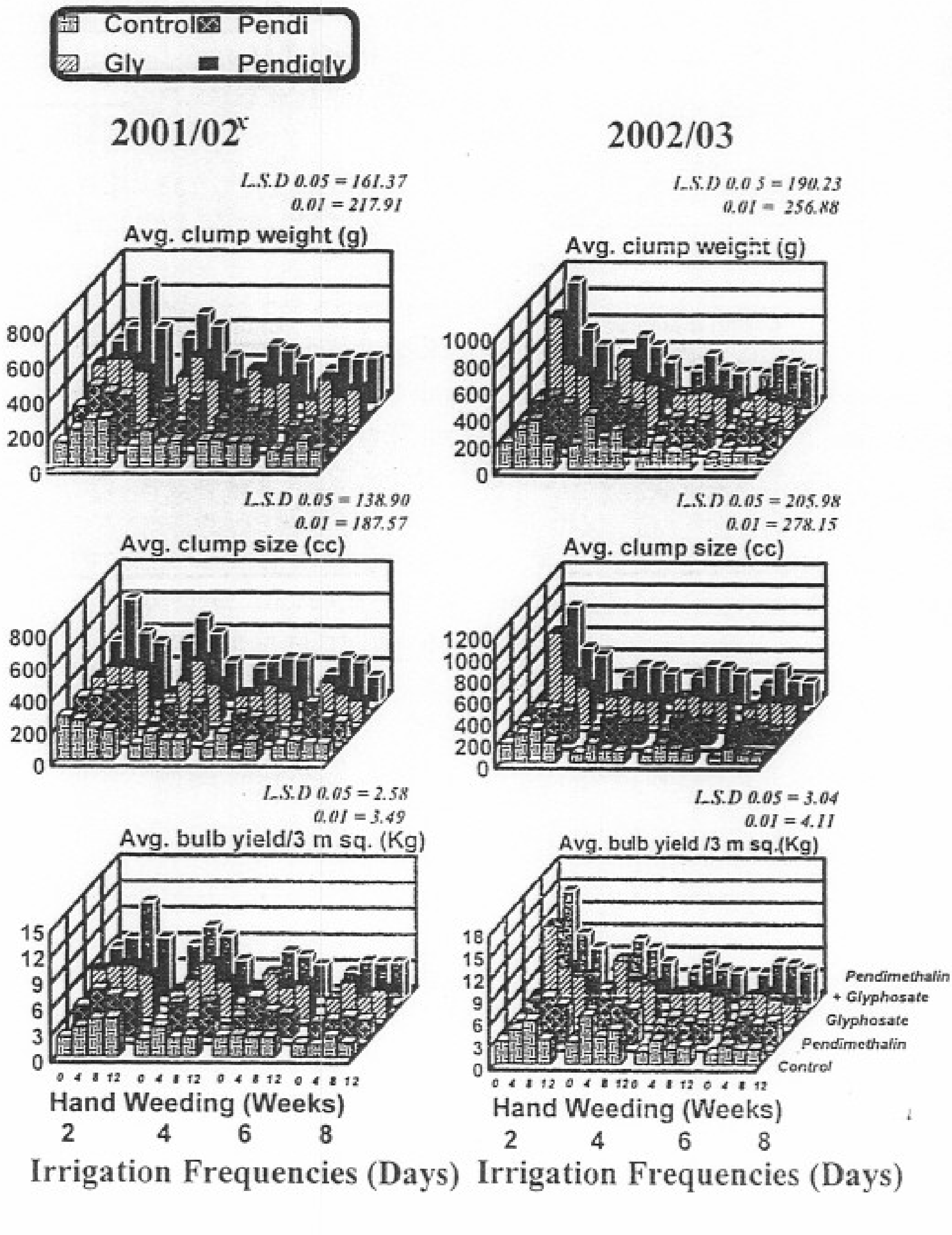

Fig.6. Average clump weight (g), average clump size (cc), and average bulb yield / sub-plot (Kg /3 m square), as influenced by the mutual interactive effects of irrigation frequencies, manual hand weeding and herbicides, during the 2001/02 and 2002/03 growing seasons, at Hada AL-Sham's Agricultural Experiment Station (Makkah AL-Mokaramah Area, KSA).

[x] *Abbreviations, in the series denote; Pendi + Pendimethalin, Gly = Glyphosate and Pendigly = Pendimethalin + Glyphosate.*

TABLE 5 . Pearson correlation coefficients of tuberose basal leaves, clump growth parameters and bulb nutrient contents, : influenced by irrigation frequencies, manual hand weeding and herbicides, in field grown Tuberoses (Polianthes tuberos L cv. "Double"), during the 2001/02 and 2002/03 growing seasons, at Hada AL-Sham's Agricultural Experiment Statio (Makkah AL-Mokaramah Area, KSA).

Parameters [a]	Basal leaves (#)	Clump diam. (cm)	Clump circum. (cm)	Clump weight (g)	Clump size (cc)	Bulb yield/ 3 m^2(#)	Bulb yield/ 3 m^2(wt)	WUE (#/ 3 m^2/m^3)	WUE (wt / 3 m^2/m^3)	Bulb N %	Bulb P %	Bulb K %
Basal leaves	——	0.82 **	0.82 **	0.67 **	0.71 **	0.61 **	0.67 **	- 0.36 **	- 0.16 **	- 0.05 ns	- 0.22 *	-0.26 **
(#)		0.81 **	0.81 **	0.67 **	0.69 **	0.62 **	0.67 **	-0.39 **	- 0.22 **	- 0.02 ns	- 0.10 ns	-0.22 **
Clump diam.			1.00 **	0.68 **	0.71 **	0.69 **	0.68 **	- 0.14 *	- 0.02 ns	- 0.01 ns	- 0.24 **	- 0.28 **
(cm)		——	1.00 **	0.64 **	0.68 **	0.62 **	0.64**	- 0.16 **	-0.00 ns	-0.03 ns	- 0.13 *	-0.36 **
Clump circum.				0.68 **	0.71 **	0.69 **	0.68 **	- 0.14 *	- 0.02 ns	- 0.01 ns	- 0.24 **	- 0.28 **
(cm)			——	0.64 **	0.68 **	0.62 **	0.64**	- 0.16 **	- 0.00 ns	-0.03 ns	- 0.13 *	-0.36 **
Clump weight					0.72 **	0.70 **	1.00 **	- 0.02 ns	0.42 **	- 0.08 ns	- 0.24 **	- 0.32 **
(g)				——	0.75 **	0.78 **	1.00 **	- 0.01 ns	0.38 **	-0.05 ns	- 0.26 **	-0.40 **
Clump size						0.73 **	0.72 **	- 0.02 ns	0.15 *	- 0.14 *	- 0.30 **	- 0.32 **
(cc)					——	0.83 **	0.85 **	- 0.07 ns	0.20 **	-0.08 ns	- 0.25 **	-0.38 **
Bulb yield/							0.70 **	0.26 **	0.19 **	- 0.05 ns	- 0.28 **	- 0.28 **
3 m^2(#)						——	0.78 **	0.31 **	0.26 **	-0.00 ns	- 0.21 **	-0.39 **
Bulb yield/								- 0.02 ns	0.42 **	- 0.08 ns	- 0.27 **	- 0.32 **
3 m^2(wt)							——	- 0.01 ns	0.38 **	-0.05 ns	- 0.26 **	-0.40 **
WUE									0.71 **	0.02 ns	- 0.18 **	- 0.14 *
(#/ 3 m^2/m^3)								——	0.70 **	0.05 ns	- 0.13 *	-0.23 **
WUE										- 0.02 ns	- 0.22 **	- 0.23 **
(wt / 3 m^2/m^3)									——	- 0.02 ns	- 0.21 **	-0.35 **
Bulb											0.13 *	0.10 ns
N %										——	0.28 **	0.01 ns
Bulb												0.23 **
P %											——	0.18 **
Bulb												
K %												——

*ns, *, ** Indicate non significant, significant and highly significant at the 0.05 and 0.01 Levels of Significance.*

[a] The upper coefficients denote 2001/2002, and the lower ones indicate the 2002/2003 growing seasons, respectively.

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تأثير تكرارات الرى ومقاومة الحشائش على أداء وسلوك نباتات التيوبروز المزروعة في الحقل ، بالمنطقة الغربية للمملكة العربية السعودية : ١ . نمو وتطور الجور البصلية ، محصول الأبصال ، كفاءة استخدام مياه الرى ومحتوى الأبصال من العناصر الغذائية

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تستهدف هذه الدراسة معظمة إنتاجية وتحسين مواصفات الجور البصلية و كذلك محصول الأبصال والبصيلات ، كوحدات إكثار لمزارعي ومنتجي التيوبروز ، من خلال دراسة أنسب معدلات تكرارات الرى وأنسب السبل لمقاومة الحشائش يدويا أو باستخدام مبيدات الحشائش ، خصوصا تحت ظروف البيئة الجافة بالمنطقة الغربية للمملكة العربية السعودية. ولذلك أجريت تجربة حقلية في تصميم القطع المنشقة المنشقة ، ذات نظام القطاعات كاملة العشوائية ، في أربعة مكررات ، وذلك لدراسة تأثيرات تكرارات الرى (رى كل يومين ، أربعة ، ستة أو ثمانية أيام) ، المقاومة اليدوية للحشائش (بدون مقاومة ، مقاومة يدوية كل أربعة ، ثمانية أو إثنى عشر إسبوعا) ، والمقاومة باستخدام مبيدات الحشائش { بدون مقاومة ، بنديميثالين (ما قبل ظهور الحشائش)، جليفوسات (ما بعد الظهور) ، بنديميثالين + جليفوسات (ماقبل وما بعد الظهور)} ومدى تأثير ذلك على نمو الجور البصلية ، محصول الأبصال والبصيلات ومدى كفاءة استخدام مياه الرى ومحتوى الأ بصال من العناصر الغذائية الكبرى ، وذلك خلال موسمى ٢٠٠٢/٢٠٠١ و ٢٠٠٢ / ٢٠٠٣ ، وكانت أهم النتائج كالتالي:

- أدى استخدام معاملات الرى كل يومين إلى إنتاج نباتات ذات نمو خضري جيد يحتوي على عدد كبير من الأوراق القاعدية ، كما أدت كذلك هذه المعاملات إلى إنتاج جور بصلية تتميز بقطر ومحيط كبيرين وكذلك أوزان وأحجام كبيرة . تتميز هذه الجور البصلية المنتجة أيضا باحتوائها على عدد كبير من الأبصال والبصيلات عالية الوزن الطازج بالنسبة للوحدة التجريبية ، وذلك بالمقارنة بمعاملات الرى الأخرى ، في كلا الموسمين .
- كان هناك اتجاه واضح وملحوظ لوجود انخفاض تدريجي في جميع الصفات المدروسة تقريبا متناسبة ومتوافقة مع تقليل كثافة تكرارات الرى أو تطويل فترات الرى ، في كلا الموسمين .
- أدى استخدام الرى كل ثمانية أيام إلى زيادة كفاءة المتر المكعب من مياه الرى ، في إنتاج أقصى عدد وأثقل وزن من الأبصال والبصيلات ، بالنسبة للوحدة التجريبية ، بصورة واضحة ، كما أوضحت النتائج أيضا وجود تناسب عكسي بين كفاءة استخدام مياه الرى و معاملات كثافة تكرارات الرى.
- أنتجت نباتات التيوبروز النامية في وحدات تجريبية تمت بها مقاومة الحشائش يدويا كل أربعة أسابيع إلى الحصول على أعلى عدد من الأوراق القاعدية ، كما أدت هذه المعاملة أيضا على إنتاج جور بصلية عالية القطر والمحيط وتتميز بوزن وحجم كبيرين ، وذات محصول وافر من الأبصال والبصيلات بالنسبة للوحدة التجريبية ، والتي تميزت بقدرة عالية جدا على زيادة كفاءة استخدام مياه الرى و ذلك بالمقارنة

بمعاملات الكنترول التي لم تقاوم بها الحشائش يدويا أو حتى بالمقارنة بمعاملات المقاومة اليدوية الأخرى .

- انخفض محتوى أنسجة الأبصال والبصيلات من العناصر الغذائية انخفاضا ملحوظا نتيجة لمقاومة الحشائش يدويا وذلك بالمقارنة بمعاملات الكنترول ، في كلا الموسمين .

- أدي استخدام البنديميثالين كمبيد ما قبل الظهور مع الجليفوسات كمبيد ما بعد الظهور، في وحدات تجريبية واحدة ، الى زيادة جوهرية في عدد الأوراق القاعدية للتيوبروز وأيضا زيادة قطر ومحيط الجور البصلية وكذلك وزنها وحجمها .

- أدت المعاملة السابقة كذلك إلى زيادة محصول الأبصال والبصيلات مقدرة كعدد أو كوزن طازج بالنسبة للوحدة التجريبية والتي تميزت بقدرة على تحسين وزيادة كفاءة استخدام مياه الرى . كما كان لهذه المعاملة أيضا الأثر الواضح في تقليل محتوى العناصر الغذائية في أنسجة الأبصال والبصيلات وذلك بالمقارنة بمعاملة الكنترول أو معاملات استخدام أى مبيد من المبيدات بمفرده .

- أنتجت نباتات التيوبروز النامية في وحدات تجريبية عوملت بالبنديميثالين ما قبل ظهور الحشائش + الجليفوسات ما بعد الظهور وتمت بها المقاومة اليدوية كل أربعة ، ثمانية أو حتى إثنى عشر إسبوعا و تم ريها كل يومين أو أربعة أيام أفضل نموات خضرية ذات عدد كبير من الأوراق القاعدية ، وجور بصلية عالية الجودة تحتوي على محصول وافر من الأبصال والبصيلات ، في كلا الموسمين ، مما يدعو إلى النصح باستخدام هذه المعاملات في التطبيق العملي .

- أظهرت نتائج تحاليل بيرسون للتلازم والإرتباط وجود علاقات تلازمية إرتباطية قوية وموجبة بين عدد الأوراق القاعدية وقطر الجور البصلية ومحيطها ووزنها وحجمها وكذلك عدد ووزن الأبصال والبصيلات المنتجة بالنسبة للوحدة التجريبية ، بينما كانت هناك علاقات تلازمية سالبة مع كفاءة استخدام مياه الرى مقدرة كعدد أو وزن الأبصال والبصيلات لكل وحدة تجريبية لكل متر مكعب من مياه الرى .

- أسفرت تحاليل بيرسون أيضا عن وجود علاقات تلازمية سالبة بين عدد الأوراق القاعدية ومحتوى الأبصال والبصيلات من العناصر الغذائية للفوسفور في الموسم الأول والبوتاسيوم في كلا الموسمين .