IMPACTS OF IRRIGATION FREQUENCIES AND WEED CONTROL IN FIELD GROWN TUBEROSES IN THE WESTERN REGION OF SAUDI ARABIA: II. VEGETATIVE GROWTH, CUT FLOWER YIELD, FLOWERING CHARACTERISTICS, QUALITY INDICES AND N,P, AND CONTENT OF LEAVES

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ABSTRACT

Controlling emergent and associated weeds, in field grown tuberose, in the Saudi Arabian Western Region Arid Zone, is extremely important, particularly under furrow irrigation system. A Split-Split-Plot field experiment, in Complete Randomized Block Design, with four replicates, was conducted, to investigate the impacts 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, cut flower yield, flowering stalk characteristics, flowering quality indices, and nutrient contents in leaves, during the 2001/2002 and 2002/2003 growing seasons.

Frequent irrigation every two and/or four days appreciably increased number of tuberose plant basal leaves, cut flower yield, flowering stalk length, diameter, weight and spike length, in comparison with frequent irrigation every six and/or eight days, in the two growing seasons. It also increased number of florets (in pairs) per spike, considerably improved visual quality rating and noticeably ameliorated tuberose flowering index However, phosphorus as well as potassium contents tended to decrease due to increasing watering frequencies or reducing watering intervals, in tuberose leaves.

Hand weeding every four weeks substantially improved vegetative growth, increasing number of basal leaves. It also increased tuberose cut flower yield, flowering stalk length, diameter, weight, and spike length considerably, in both seasons, in comparison with either the unweeded controls or other hand weeding treatments. Moreover, hand weeding every eight or twelve weeks were notably beneficial to tuberose vegetative growth, yield of cut flowers as well as flowering stalk characteristics, in comparison to unweeded controls. Frequent hand weeding every four weeks also remarkably produced the highest number of flowers per spike, superior quality rating associated with noticeably high flowering index, in comparison to either unweeded controls or other weeding treatments. Nevertheless, it conversely recorded the lowest percentages of N, P and K contents, in comparison to the unweeded controls.

Pendimethalin plus glyphosate noticeably improved tuberose different characters and parameters, in both seasons, followed by glyphosate and pendimethalin, in a descending order, in comparison to the untreated controls. Tuberose leaves of plants treated with pendimethalin plus glyphosate remarkably registered the lowest nutrient contents of N, P and K, in both seasons.

Plants which, received the preemergence pendimethalin plus the postemergence glyphosate, weeded manually every four, eight and/or even twelve weeks, and frequently irrigated every two and/or four days, exhibited conspicuous performances and noticeable floral behavior.

Tuberose plant vegetative growth (number of basal leaves) was strongly correlated positively with cut flower yield, flowering stalk length, diameter, weight, spike length, number of flowers/spike, visual quality rating and flower index, with highly significant correlation coefficients, in both seasons. Conversely, tuberose leaf nutrient contents (N, P and K) were considerably and negatively correlated with tuberose number of basal leaves.

Additional Index Words: Tuberose, Polianthes tuberosa, L., Irrigation Frequency, Water regimes, Manual Hand Weeding, Herbicides, pendimethalin, glyphosate, Vegetative Growth, Cut Flower Yield, Flowering Characteristics, Flowering Stalk Quality Indices.

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INTRODUCTION

Tuberose (*Polianthes tuberosa, L.*), cv. "Double", an ornamental bulbous plant native to Mexico, is one of the most important cut flowers in the tropical and subtropical areas (Benschop, 1993). The long spikes of ivory-waxy and fragrant flowers are exceptionally aesthetic and they are used for cut flowers and for essential oil, cosmetics and perfumery industries (Benschop, 1993; and Reid, 2004). Peoples all over the World particularly Middle Eastern, Far Eastern and even Western ones and also florists highly regard and adore its sweet smelling fragrance. The gorgeous adorable tuberose was introduced, in the last decade, in the Saudi Arabian Western Region, hoping establishment and acclimatization. Successful establishment with substantial performance was attained (El-Naggar and Byari, 1999 a, b, c, and d). However, comprehensive research programs were compulsory required for amelioration and improvement, particularly under the harsh arid climate, high temperature exceeding 40 °C (Fig. A) most of the year round, and water shed tribulations prevailing in the area.

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Boodley (1981) reported that irrigation, especially, under arid climates is extremely indispensable to obtain good quality crops. However, numerous researchers working with different bulbous ornamentals revealed that, increasing irrigation or watering frequencies, water quantities and/or levels, for irrigating flowering bulbous ornamentals, immensely hastened vegetative growth, profoundly improved cut flower yield and greatly enhanced flowering quality characteristics and water use efficiencies in Tuberose (Halepyati *et al.*, 1995; and Halepyati *et al.*, 2002); Narcissus (EL-Naggar and Nassar, 1994); Gladiolus (Maggio *et al.*, 1993; Alvino *et al.*, 1998; and Bastug *et al.*, 2006); Bird of Paradise (Abo EL-Ghait, 1993); and Ornithogallum (EL-Hanafy *et al.*, 2006). Nevertheless, water stress conditions due to drought and/or water deficit dramatically reduced vegetative growth, length and weight of tuberose marketable inflorescences, and markedly shortened the flowering period of tuberose plants (AL-Moftah and AL-Humaid, 2005). Moreover, sever water stress, pronouncedly altered the physiology of field grown tuberoses intensely. It decreased stomatal frequency and conductance, leaf water potential, osmotic potential, turger potential, relative water content, chlorophyll content, carbon assimilation rate, and transpiration rate, according to AL-Moftah and AL-Humaid, 2004. Besides, Pascale *et al.*, 2001, also reported that, water stress or severe water deficit in field-grown gladiolus, not only reduced photosynthetic rate by 67 % and leaf water potential (from – 2.1 to – 1.4 Mpa), but also had, overwhelmingly, complex effects on the whole plant physiology. However, physiological processes affected by water stress could be partially recovered by irrigating plants, during the most critical periods, when water requirements were highly available.

Intensive growth of grasses such as Bermuda grass (*Cynodon dactylon, L.)* and Nutsedge (*Cyperus rotendus)* as well as other common broad-leaves weeds, in field-grown tuberoses, in the Western Region of Saudi Arabia, represents a major challenging problem for the scanty weed-sensitive-competitor tuberose, especially, under furrow irrigation system. Consequently, weed control manipulation strategy was worthwhile investigation for improving tuberose cut flower yield and quality. Weed control strategies have been adopted and investigated, in the literature, by many researchers and scientists for numerous bulbous ornamentals. These Strategies were achieved through several techniques including weeding (DongChun *et al.*, 2000, on gladiolus (*Gladiolus grandiflorus cv. "Spic and Sspan"*); Pennucci, 2000 on Iris; Mohanty *et al.*, 2002, on tuberose; and Santosa *et al.*, 2006, on Elephant Foot Yams; hoeing and/or soil loosening (Dwibeddi and sen, 2000, on Elephant Foot Yam; Mulching (Chahal *et al.*, 1994; and Widaryanto *et al.*, 1997, on Gladiolus; and Hossain, 2005, on Turmeric; and the use of herbicides (Bullitta *et al.*, 1996, on Crocus; Avilkumar and Reddy, 2000, on Turmeric; Panwar *et al.*, 2005 a & b, on tuberose; and Richardson and Zandstra, 2006, on Gladiolus. Notwithstanding, frequent hand weeding and/or hoeing was proven not only effective in reducing the adverse effects of weeds, but also beneficial in improving vegetative growth, increasing cut flower yield and enhancing quality characteristics of tuberose according to Mohanty *et al.*, 2002 and Panawar *et al.*, 2005 b, as well as enhancing gladiolus plants performances (Chahal *et al.*, 1994; Laskar and Jana, 1996; and DongChun *et al.*, 2000). Nonetheless, hand weeding and/or hoeing, in field grown bulbous ornamentals, is extremely arduous, backbreaking, laborious and economically costly (Rethinam *et al.*, 1978; and Pushpalatha *et al.*, 2000), especially under the harsh climate of the arid zone, in the western region of Saudi Arabia. Albeit herbicides are not preferably allowed for uses, particularly in edible subterrarian horticultural crops, due to water contamination, air pollution, soil microorganisms' hazards, health hazards and food risks (Hossain, 2005), they are used safely and extensively, however, in field grown bulbous ornamentals. Therefore, herbicides, as an alternative or supplementary auxiliary approach, were thought of and seriously suggested for weed control in this investigation.

Pendimethalin {*N- (1-ethylpropyl)-2,6-dinitro-3, 4-xylidine*} is an orange –yellow crystalline solid, with nutty or fruit-like odor. It is well-known as Accotab, G0-Go-San, Pre-M, Herbadox, Penoxalin, Prowl, Sipaxol, Stomp 400SC, Stomp 330 EC, Way up, Pendulum and/or Pendimethalin, in the agricultural trade business, as commercial trade names (WSSA, 1989). Pendimethalin, at a rate up to 4.5 Kg *a. i.* /ha, demonstrated effective weed control of broad leaves and some grassy weeds without any injury or phytotoxic effects, in many bulbous ornamentals, herbaceous perennials and landscape plantings (Skroch *et al.*, 1994; Al-Khatib, 1996; Ivanova, 1999; and Richardson and Zandstra, 2006). Although pendimethalin did not significantly affected post harvest performance and vase life of tuberose flowering spikes according to Murthy and Gowda, 1994, it greatly enhanced tuberose vegetative growth, cut flower yield and quality characteristic parameters in the field according to Murthy and Narayana, 1993; and Panwar *et al.*, 2005 b. It also improved flowering yield and cut flowers traits in Tulip (Talia and Stellacci, 1980); and Gladioli (Singh *et al.*, 2000; Arora *et al.*, 2002; Dhiman, 2003; and Kori and Patil, 2003). Glyphosate *{N- (Phosphonomethyl) glycine}* is also used as a post-emergence broad-spectrum, non-selective systemic herbicide. It is used for controlling annuals and perennials, including grasses, sedges and broad-leaved weeds (Kidd and James, 1991). Glyphosate acts primarily on blocking or inhibiting the shikimate pathway enzyme EPSP synthase, thereby interfering with amino acid metabolism (Eason *et al.*, 2000). It didn't show, however, any adverse effect(s) in nursery lines and gladiolus as well as many other bulbous ornamentals including Dutch amaryllis, Agapanthus and Dutch iris (Bing, 1979; and Manuja *et al.*, 2005), when applied at rates up to 16 lb/acre. Glyphosate, however, exhibited no phytotoxic symptoms in field-grown crocus (*Crocus sativus, L.*), because of its fast degradability recorded by *HPLC* analyses, according to Solinas *et al.*, 1997. Moreover, glyphosate as a post emergence non-selective systemic herbicide was found not only effective in controlling weeds, particularly the grassy ones, but also successfully useful in improving cut flower yield and enhancing quality characteristics in gladiolus (Wilfert and Waters, 1976) and tuberoses (Panwar *et al.*, 2005 b).

The study reported herein was undertaken to evaluate the efficiency of different weed control approaches; hand weeding; herbicidal treatments, including pendimethalin, glyphosate and their combinations, on tuberose vegetative growth, cut flower yield, flowering characteristic performances and flowering stalk quality indices, under different irrigation frequency regimes, in the Western Region Arid Zone of Saudi Arabia.

MATERIALS AND METHODS

The concurrent investigation was conducted and executed at Hada AL-Sham's Agricultural Experimental Station, 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 Complete Randomized Block Design, 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) in the sub-sub-plots. Detailed materials, methods and experimental procedures, however, were documented by El-Naggar and Byari 2007 a & b.

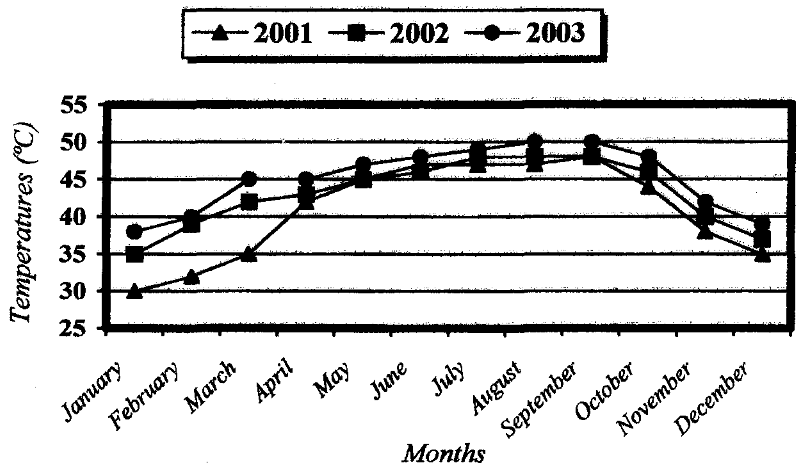

Fig. A: Maximum monthly temperatures (°c), at Hada Al-Sham's Agriculture Experiment Station (Makkah Al-Mokaramah Area, KSA), over three consecutive gregorian years of 2001,2002 and 2003.

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) 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.

Irrigation Frequencies and Watering Intervals

Irrigation frequency treatments were randomly assigned to the whole plots, which received certain amount of water, delivered through main, sub-main and sub-sub-main plastic pipes. 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-par active pressure, to the experimental plots, from these tanks. Irrigation treatments; 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, to reach field capacity, 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, upon termination of the experiment, registered 703.00, 352.5, 235.08, and 172.87 cubic meter of water per whole plot, in correspondence with irrigation every 2, 4, 6 and 8 days on sequence, for the entire blooming period, which took about 16 months, due to continual blooming under the favorable prevailing conditions. However, the experiment was terminated intentially when blooming became noticeably light. 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 emergence and plant establishment took place.

Weed Control Treatments

Manual hand weeding and hoeing

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

Herbicidal Treatments

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. Furthermore, thorough agitation was also performed to resusspend 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 is used at the rate of 1.0 % a. i. /ha, in this experiment, and applied 60 days from initial bulb planting, as post emergence treatment, to the assigned sub-sub plots. However, dry ammonium sulphate (20 % N), 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

Vegetative Growth, cut Flower Yield and Quality Parameter's Measurements

Tuberose flowering stalks were regularly harvested, throughout the whole period of the project, according to maturity, and then subjected to the different data measurements processes. Measurements were recorded throughout the growing season, on all produced flowering stalks of tuberose plants. Measurements included number of basal leaves per plant, yield of flowering stalks produced per sub-sub-plot, stalk length (cm), diameter (cm), spike length (cm), flowering stalk weight (g), number of florets per spike (in pairs), visual quality rating, and flowering index. N, P, and K in tuberose leaves were also determined. Quality rating was based on a scale of one to ten; 1-3 = very poor; 3-6 = poor; 6-8 = good; and 8-10 = superior quality. The weight/length ratio (W/L), which was expressed as g/cm, as a criterion, for flowering stalk quality, was used according to Morisot *et al.*, (1998) as a flowering quality index, estimated as W/L ratios x yield per sub-sub plots. The project was intentionally terminated on October 23rd, and 25th in 2002 and 2003, respectively, when cut flower yield slow down and became relatively light, even though tuberose plants basal leaves were still very green and absolutely healthy, because tuberose plants act as perennial under the hot Arid Zone Saudi Conditions, and according to Armitage and Laushman, (1990); Yuniarti *et al.*, (1998); and EL-Naggar and Byari, (1999c).

Chemical analyses

Representative samples of tuberose basal leaves representing each experimental plot were collected from the middle part of the plant upon 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 leaves 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 calorimetrically 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 Programs (SAS, 1999; Steel and 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, Pearson Correlation Analyses (PCA) were also performed for tuberose basal leaves, cut flower yield and different flowering parameters & quality indices, as well as leaf nutrient content.

RESULTS AND DISCUSSIONS

Impacts of Irrigation Frequencies

Irrigation water is extremely viable and very crucial limiting factor, in biological systems and lives of plant growth and development. Boodley (1981) reported that, irrigation, particularly, under arid climates is exceptionally indispensable to obtain good quality crops. Irrigation frequency regimes strongly influenced vegetative growth as well as cut flower yield and flowering traits and parameters, in field-grown tuberose.

Vegetative Growth, Cut Flower Yield and Flowering Characteristics

Data presented in Table 1, exhibit the performances of tuberose plant vegetative growth, cut flower yield and flowering characteristics as functions of the different irrigation frequency regimes. Watering frequencies strongly affected all tuberose parameters and traits, in both seasons. Evidently, frequent irrigation every two and/ or four days appreciably increased number of tuberose plant basal leaves, cut flower yield, flowering stalk length, diameter, weight and spike length, in comparison with frequent irrigation every six and/or eight days, in the two growing seasons. However, considerable statistical differences were detected among irrigation frequency treatments, in both seasons. It is worth notable that, as the frequency of irrigation was increased (reducing watering intervals), vegetative growth as well as cut flower yield and associated flowering stalk parameters were increased accordingly and vise versa. Nevertheless, breaking down the three degrees of freedom, of the equally spaced irrigation frequency treatments, into one single degree of freedom, through orthogonal polynomial regression analyses, revealed linear, quadratic or cubic statistical responses (Table 1). Curve best fitting of these orthogonal polynomials resulted in strong negative linear patterns (Fig. 1), expressing the different trait performances, associated with high coefficient of determinations (R^2 = 0.97 to 0.99), supporting obtained results. Nevertheless, the favorable impacts of short watering intervals, irrigation every two and/or four days, or intensive watering frequencies, increasing soil moisture content in tuberose tuberous root rhizosphere, in improving vegetative growth, yield of cut flowers and flowering stalk parameters, might be responsible for such performance(s). Boodley (1981) reported that, irrigation, especially under arid climates is extremely indispensable to obtain good quality crops. High available soil moisture content around tuberose root rhizosphere, might perhaps furnished more minerals and nutrient availabilities, via facilitating absorption, which subsequently, in turns, enabled tuberose plants to develop well and exhibit such noticeable behavior. Numerous researchers and floriculturists also stressed the significant role of irrigation water quantity and/or levels, in improving and hastening growth performances of many bulbous ornamental, according to Halepyati *et al.*, (1995); and Halepyati *et al.*, (2002) on tuberose; EL-Naggar and Nassar (1994) on narcissus; Maggio *et al.*, (1993); Alvino *et al.*, (1998); and Bastug *et al.*, (2006) on gladiolus; Abo EL-Ghait (1993) on Bird of Paradise; and EL-Hanafy *et al.*, (2006) on Ornithogallum.

Flowering Stalk Quality Indices

Tuberose flowering stalk quality indices; florets number per spike, quality rating and flower index were profoundly influenced by the different irrigation frequency regimes (Table 2). Bountiful watering and irrigation every two and/or four days greatly increased number of florets (in pairs) per flowering spike, considerably improved quality rating and noticeably ameliorated tuberose flowering index, in both seasons, in comparison to other irrigation frequency treatments, although statistical differences were also detected among the different watering frequency regimes. It is worthwhile notable that, lengthening watering intervals and/or decreasing frequencies of watering, obviously, resulted in reducing flowering stalk quality indices. On the contrary, reducing watering intervals or increasing watering frequencies tended to noticeably enhance tuberose quality parameters and indices, in both seasons. Orthogonal polynomial regression analyses, with best curve fitting, yielded highly significant negative linear and/or quadratic patterns (Fig. 2), describing these performances, associated with high coefficient of determinations, ascertaining obtained results. The immensely appreciable performances of tuberose flowering stalk quality indices, due to increasing watering frequencies or shortening watering intervals, might be attributed to high available soil moisture content provided through frequent irrigation. This subsequently might have facilitated tuberose root system absorption of ideally required minerals and nutrients, enhanced plant endogenous water status, and also improved photosynthetic activities and internal plant physiological metabolism. Conversely, the comparable adverse effects of reducing watering frequencies, particularly under the harsh environmental conditions of the western region arid zone, in Saudi Arabia, might be accountable for relatively poor qualities. Reducing irrigation frequencies or lengthening watering intervals might have created drought conditions and imposed sort of water deficit or water stresses. These consequently might have altered plant physiological status, resulting in deteriorating tuberose flowering stalk quality indices. Similar results were also published by Pascale et *al.,* (2001) on gladiolus; and AL-Moftah and AL-Humide (2004 & 2005) on tuberose.

Leaf Nutrient Contents

Tuberose leaf nutrient contents; N, P and K percentages were markedly affected by the different irrigation frequency regimes, resulting in either non-significant or significant responses (Table 2). Statistical analysis revealed that, nitrogen content was not significantly affected by watering frequencies, in both seasons. However, phosphorus as well as potassium contents tended to decrease due to increasing watering frequencies or reducing watering intervals. These behavioral performances were illustrated on Fig. 2, through orthogonal polynomial regression analyses, with curve best fitting, exhibiting non-significant (N%), or positive linear responses for phosphorus and potassium. These performances might be attributed to dilution effects resulted from vigorous vegetative growth and increased number of basal leaves, associated with more frequently irrigated plants, in comparison to less frequent irrigations, associated with comparatively lower number of basal leaves and plant vigor.

Impacts of Manual Hand Weeding

Hand weeding has long been traditionally practicised, by farmers and growers, to remove competitive unnecessary grown plants, reducing its detrimental effects, to improve crop's growth and development.

Vegetative Growth, Cut Flower Yield and Flowering Characteristics

Manual hand weeding treatments immensely influenced tuberose vegetative growth, yield of cut flowers and flowering stalk characteristics, in both seasons (Table 1). Frequent hand weeding every four weeks substantially improved vegetative growth, increasing number of basal leaves. Monthly hand weeding also increased tuberose cut flower yield, flowering stalk length, diameter, weight, and spike length considerably, in both seasons, in comparison with either the unweeded controls or other hand weeding treatments. However, hand weeding every eight or twelve weeks were significantly beneficial to tuberose vegetative growth, yield of cut flowers as well as flowering stalk characteristics, in comparison to unweeded controls, although statistical differences were obviously existed between both treatments. Equally spaced hand weeding treatment's degrees of freedom, broken down into one single degree, employing orthogonal polynomial regression analyses, with best curve fitting (Fig. 3), yielded either quadratic or cubic patterns of responses, describing anticipated tuberose trait performances sustaining previous results. Frequent hand weeding and/or hoeing was proven not only effective, in plummeting the unfavorable effects of weeds, but also advantageous in improving vegetative growth, increasing cut flower yield and enhancing flowering stalk characteristics of tuberose plants, according to Mohanty *et al.,* (2002); and Panwar *et al.,* (2005 b); as well as enhancing gladiolus plant performances in accordance with Chahal *et al.,* (1994); Laskar and Jana (1996); and DongChun *et al.,* (2000).

Flowering Stalk Quality Indices

Manual hand weeding, generally, affected tuberose flowering stalk quality indices, including florets number in pairs per spike, quality rating and flowering index, in both seasons (Table 2). Apparently, frequent hand weeding every four weeks remarkably produced the highest number of florets per spike, superior quality rating associated with noticeably high flowering index, in comparison to either unweeded controls or other weeding treatments. However, weeding every eight and/or twelve weeks produced conspicuously better flowering stalk quality indices, in comparison to the unweeded controls, although statistical differences were recorded for both treatments. Orthogonal polynomial regression analyses, with best curve fitting, yielded substantial quadratic responses (Fig. 4), illustrating and also demonstrating the different quality indices traits, ascertaining achieved results. The perceptible performances of tuberose flowering stalk quality indices, due to the impacts of frequent hand weeding, might be attributed to the significant role and function of comparable intensive weeding every four weeks, in particular. However, frequent hand weeding and weed uprooting might have almost eliminated or at least minimized weed/tuberose competitions, which denote and imply much more soil moisture content, abundant of minerals and nutrients in the soil solution, wider spaces, and more open canopy solar energy. These subsequently might have translated into powerfully ideal environmental and nutritional conditions, improving plant growth and development, allowing increases in photosynthetic activities and abundance of photosynthates, reflected indirectly on plant growth and vigor, resulting in highly appreciated flowering stalk quality indices.

Leaf Nutrient Contents

Endogenous tuberose leaf nutrient content, including major elements N, P and K, were markedly affected by hand weeding frequencies, in field grown tuberoses (Table 2). Nutrient content, in tuberose leaves, exhibited strong statistical performances, in both seasons. It recorded the lowest percentages of N, P and K contents, due to frequent hand weeding every four weeks, in comparison to the untreated controls, which registered the highest percentages, in both seasons. Furthermore, frequent weeding every eight and/or twelve weeks also revealed low nutrient in tuberose leaves, when compared to the untreated controls. These performances are well expressed by the orthogonal polynomial response curves (Fig. 4), yielding mostly negative quadratic patterns of responses, with fairly sensible coefficient of determinations, in the two growing seasons. However, the considerable reduction in tuberose leaf nutrient contents, established due to frequent hand weeding may be accredited to the strong impacts of these treatments on tuberose vegetative growth and number of basal leaves produced by plants. Frequent weeding and weed intensive removal and eliminations might have permitted noticeable growth and development characterized by producing healthy and numerous basal leaves. Subsequently, nutrient contents might have physiologically diverted among produced leaves, establishing what is so called the dilution effects.

Impacts of Herbicidal Treatments

Herbicides manipulation and management, have long been used extensively, either as an alternative or auxiliary supplementary approach, for controlling weeds, instead of the arduous, backbreaking, laborious and expensive mechanical weeding according to Rethinam *et al.,* (1978); Pushpalatha *et al.,* (2000); and Panwar *et al.,* (2005 b), in many bulbous ornamentals.

Vegetative Growth, Cut Flower Yield and Flowering Characteristics

The different herbicidal treatments, profoundly affected tuberose different traits and parameters, in field grown tuberoses (Table 1). Tuberose number of basal leaves (vegetative growth criterion), cut flower yield, flowering stalk length, diameter, weight and spike length were immensely enhanced, due to the different herbicidal treatments. Pendimethalin plus glyphosate noticeably improved tuberose different characters and parameters, in both seasons, followed by glyphosate and pendimethalin, in a descending order, in comparison to the untreated controls. However, strong significant differences were statistically recorded among all herbicidal treatments, including untreated controls, in both seasons. It is worth notable that, although protected Fisher's L.S.D values were highly significant for all studied traits, orthogonal contrast was essentially manipulated as an efficient tool for more specific mean comparisons, answering particular question(s), by breaking down herbicidal treatments degrees of freedom into single ones. Orthogonal contrast statistical analyses revealed highly significant mean comparisons for all possible contrasts. These analyses indicated strong positive synergistic simulative effects, for both herbicides (pendimethalin and glyphosate), when they existed together, as preemergence and postemergence herbicidal application. This might perhaps explain the superiority of the combined treatment over using either herbicide separately, as well as the over the untreated controls, in effectively and efficiently controlling weeds (EL-Naggar and Byari (2007 a & b), eliminating and hindering weed/tuberose competitions, and subsequently enhancing tuberose yield and flowering traits considerably. However, Murthy and Narayana (1993); and Panwar *et al.,* (2005 b) on tuberose; Talia and Stellacci (1980) on tulip; and Singh *et al.,* (2000); Arora *et al.,* (2002); Dhiman (2003); and Kori and Patil (2003) on gladiolus, reported that, pendimethalin greatly enhanced vegetative growth, and improved cut flower yield characteristics. It were also reported that, pendimethalin was exceptionally effective, in controlling weeds, without any apparent phytotoxic effects in many grown bulbous ornamentals, herbaceous perennials, and even landscape planting according to Skroch *et al.,* (1994); AL-Khatib (1996); Ivanova (1999) and Richardson and Zandstra (2006). Glyphosate was also used successfully, in field grown gladiolus, Dutch amaryllis, agapanthus crocus and Dutch iris, without any phytotoxicity symptoms or even adverse effects according to Bing (1979); Solinas *et al.,* (1997); and Manuja *et al.,* (2005), when applied at rates up to 16 lb/acre. It was also successful in improving cut flower yield and quality characteristics of gladiolus plants according to Wilfert and Waters (1976), as well as tuberose plants according to Panwar *et al.,* (2005 b).

Flowering Stalk Quality Indices

Data presented on Table 2, exhibited the immense performances of tuberose flower quality parameters, as functions of the different herbicidal treatments. Obviously, sub-sub-plots treated with the preemergence and the post emergence herbicides (pendimethalin plus glyphosate) produced flowering stalks carrying the highest number of florets, in pairs per spike, appreciably rated and ranked superior, and considerably recorded the highest flower index, in both seasons, in comparison with untreated controls or those treated with either herbicide, although each herbicide applied alone was also effective in enhancing flowering stalk quality indices, when compared to the untreated controls. The efficacy of the different herbicidal treatments, in controlling weeds (EL-Naggar and Byari (2007 a &b), was perhaps responsible for hindering weed/tuberose competitions, which might have provided tuberose treated sub-sub-plots ideal opportunity to take advantages and benefited from all environmental and nutritional resources, which, in turns, might have been reflected on noticeably conspicuous flowering stalk quality indices. Manuja *et al.,* (2005) emphasized the importance of combining preemergence and postemergence herbicidal chemicals, in controlling weeds, and consequently improving gladiolus plant performances. Arora *et al.,* (2002); and Kori and Patil (2003) on gladiolus, also reported appreciable enhancements as well as increases in number of flowers per spike of gladiolus, due to pendimethalin application at rates of 0.5 and 1.00 Kg/ha. Moreover, Panwar *et al.,* (2005 b), further reported enhancement in floral characteristics, attributable to applications of either pendimethalin or glyphosate, when applied separately, in field grown tuberoses.

Leaf Nutrient Contents

Tuberose leaf nutrient contents were considerably influenced by the different herbicidal treatments, in both seasons (Table 2). Tuberose leaves of plants grown in sub-sub-plots treated with pendimethalin plus glyphosate remarkably registered the lowest nutrient contents of N P and K, in both seasons, in comparison to those of the untreated controls, which recorded the highest percentages of these major elements. Plants grown in sub-sub-plots treated with either pendimethalin or glyphosate also exhibited noticeably lower percentages of the anticipated elements, when compared to the untreated controls. These performances may be attributed mainly to substantially vigorous tuberose plants characterized by well-developed vegetative growth, grown in well-controlled weed's sub-sub-plots, having numerous basal leaves, thus dilution effects might have probably occurred accordingly, resulting in such achieved results, proportionally to the untreated controls.

Impacts of Mutual Interactive Effects

The three investigated factors, manuscripted herein; irrigation frequency regimes, manual hand weeding, and herbicides, reciprocally and mutually interacted collectively yielding non-significant, significant and highly significant two and/or three way interactive effects, for tuberose vegetative growth, cut flower yield and associated flowering characteristics, as well as flowering stalk quality indices (Tables 3 & 4), in the two growing seasons. The three way (third order interactions) interactive effects, however, have more broaden scope than the two way ones. It specifically describe tuberose different traits and parameter's performances, as functions of the three investigated factors, when they existed communally, drawing the whole picture of such performance(s), in comparison to the second order ones (two-way interactions). Therefore, discussions, in relation to this investigation would only concentrate and/or focus on the three way interactions.

Irrigation Frequencies x Manual Hand Weeding x Herbicidal Treatments

Vegetative Growth, Cut Flower Yield and Flowering Characteristics

Figure (5) illustrates tuberose plant vegetative growth, cut flower yield, flowering characteristics and associated flowering stalk indices, as influenced by the reciprocally mutual interactive effects, in the two growing seasons. Irrigation frequency regimes, manual hand weeding and herbicidal treatments, mutual interactive effects, exhibited strong highly significant impacts on tuberose trait's performances. Obviously, plants grown in sub-sub-plots, received the preemergence pendimethalin plus the postemergence glyphosate, weeded manually every four, eight and/or even twelve weeks, and frequently irrigated every two and/or four days, exhibited prominent performances and noticeable floral behavior. These plants were characterized by perceptibly vigorous vegetative growth expressing high numbers of basal leaves, remarkably higher cut flower yield, and markedly taller flowering stalks. In contrast, plants growing in experimental units non-herbicidally treated at all as controls, unweeded manually at all or weeded every twelve or even eight weeks and subjected to stressful irrigation every eight or even six days unfavorably revealed the opposite effects. Nevertheless, The prominent conspicuous performances might be attributed to the strong impacts of each investigated factor, particularly when they existed and applied simultaneously together, functioning synergistically in the anticipated experimental units, showing these results.

Flowering Stalk Characteristics

Flowering stalk characteristics, including diameter, weight and length were also affected markedly by the three investigated factors, when they interacted reciprocally, in both seasons (Fig. 6). Tuberose flowering stalks produced by plants growing in sub-sub-plots treated with pendimethalin plus glyphosate, subjected to frequent weeding every four, eight as well as twelve weeks and irrigated frequently every two and/or four days were remarkably wider, heavier and taller than those produced by plants non-herbicidally treated as controls, not weeded at all as controls, or weeded every twelve or eight weeks, and undergone frequent irrigation every twelve or even six days, which showed contrasting performances. However, tuberose plant's flowering stalk performances are, obviously the sum of irrigation regimes, hand weeding and herbicidal treatments, when they function concomitantly.

Flowering Stalk Quality Indices

Figure (7) exhibits florets number per spike, visual quality rating and flowering index of tuberose flowering stalks (flowering quality criteria), as influenced by the reciprocally interacted factors, under investigation. Flowering stalk index, expressed as length/weight ratios produced by experimental units (g/cm/3 m^2) as well as florets number/ spike and the visual quality rating, showed conspicuous performances for flowering stalk produced by plants grown in experimental units, where weeds were controlled using pendimethalin + glyphosate, frequently weeded every four, eight and/or even twelve weeks and subjected to frequent watering every two and/or four days However, according to Zimdahl (2004), weed growth and interference, with such a crop, result in immense reduction and deterioration in crop yield. Deterioration in crop yields, due to weeds, result from their multifarious ways of interfering with crop growth and crop culture. Weeds compete with crops for one or more plant growth factors, such as mineral nutrients, water, solar energy and spaces and they significantly hamper crop cultivation operations. This, obviously, may elucidate the noticeably conspicuous performances of tuberose vegetative growth, yield of cut flower, flowering stalk traits and associated flowering quality indices. The existence of pendimethalin plus glyphosate together, were powerfully efficient in controlling preemergence as well as post emergence weeds, amplified with frequent hand weeding treatments, resulting in noticeably highly significant weed control efficiencies, and remarkably low weed-water use efficiencies, whether estimated based on weed numbers or on unit dry weight, according to EL-Naggar and Byari (2007 a & b). Low weed-water use efficiencies, however, in the anticipated treated experimental units, means high water use efficiencies for tuberose as competitive crop, particularly when tuberose plants were subjected to frequent irrigation every two and/or four days. Consequently, tuberose plants may probably grown in ideal favorable environment, providing abundant of soil moistures, rich in minerals and nutrients in the soil solution, to the shallow-fibrous root system of tuberose, enhancing plant water relations, particularly under such harsh high temperature exceeding 40 °C (Fig. A), in the Western Region, and also hastening flowering stalk initiation and development. It also might have furnished more room and spaces for plant growth and development, providing canopy with more solar energy, which may result in higher photosynthetic activities, in favor and beneficial to floral development. It also probably provided protection for the growing tuberose plants against insects and diseases, which always associated with weeds, in favor of conspicuously developing cut flowers.

Pearson Correlation Analyses

Person correlation analyses, of the studied traits and parameters matrix, describing behavioral mutual correlative relationships among tuberose characters, as well as correlation coefficients, are demonstrated in Table (5). Tuberose plant vegetative growth (number of basal leaves) was strongly correlated positively with cut flower yield, flowering stalk length, diameter, weight, spike length, number of florets/spike, visual quality rating and flower index, with highly significant correlation coefficients, in both seasons. Conversely, tuberose leaf nutrient contents (N, P and K), were considerably and negatively correlated with tuberose number of basal leaves. This disclosed that, as number of basal leaves increased, resulting in vigorous vegetative growth, cut flower yield, flowering stalk characteristics and qualities would remarkably improved correspondingly. On the other hand, such improvement in tuberose vegetative growth would subsequently lead to noticeable reductions and decline in endogenous nutrient contents, in tuberose leaves. However, it is worthwhile reporting that, tuberose leaf nutrient contents were immensely correlated negatively with all tuberose characters and traits, in both seasons. These relationships conferred that, as leaf nutrient contents were dramatically reduced, in tuberose leaves, vegetative growth would immensely increased. Consequently, tuberose yield of cut flowers as well as the associated quality characteristics would also notably enhanced, accordingly.

Table (1): Impacts of irrigation frequencies, hand weedings and herbicides on vegitative growth, cut flower yield and flowering 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.)/ plant	Basal leaves (#)		Cut flower yield / sub-sub-plot ($3m^2$)		Flowering stalk length (cm)		Stalk diameter (cm)		Stalk weight (g)		Spike length (cm)	
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)[x]												
Two	166.20 a	192.68 a	55.35 a	60.43 a	96.22 a	106.27 a	1.20 a	1.30 a	98.04 a	129.27 a	33.92 a	36.80 a
Four	132.73 b	115.77 b	36.42 b	46.48 b	81.23 b	097.17 b	0.95 b	1.04 b	88.46 b	112.99 b	30.81 b	32.80 b
Six	073.45 c	084.51 c	28.63 c	34.06 c	72.80 c	085.94 c	0.87 c	0.95 c	83.06 c	092.38 c	26.64 c	29.67 c
Eight	048.18 d	053.00 d	18.45 d	21.25 d	58.43 d	068.35 d	0.72 d	0.83 d	67.89 d	085.17 d	20.35 d	22.06 d
F-Test	**	**	**	**	**	**	**	**	**	**	**	**
LSD 0.05	11.19	13.77	3.37	2.95	2.54	2.87	0.03	0.04	4.12	3.83	1.24	1.94
0.01	16.08	19.78	4.84	4.24	3.66	4.13	0.05	0.06	5.91	5.51	1.78	2.78
Polynomial regression												
Linear	**	**	**	**	**	**	**	**	**	**	**	**
Quadratic	ns	**	**	ns	ns	**	**	**	ns	**	**	*
Cubic	**	*	*	ns	**	ns	**	**	*	**	ns	ns
● Manual weeding (Weeks)												
Control	086.88 d	093.59 d	27.25 d	28.52 d	73.83 c	85.45 b	0.88 c	0.96 d	73.09 c	095.31 c	25.76 d	28.10 c
Four	132.03 a	126.52 a	42.50 a	53.15 a	80.65 a	93.41 a	1.00 a	1.10 a	92.51 a	113.92 a	29.79 a	32.04 a
Eight	104.75 b	115.63 b	37.90 b	42.68 b	78.31 ab	92.11 a	0.93 b	1.05 b	88.18 ab	109.60 a	28.62 b	31.22 a
Twelve	096.91 bc	110.23 c	31.20 c	37.87 c	75.90 bc	86.76 b	0.92 b	1.02 c	83.68 b	100.98 b	27.56 c	29.98 b
F-Test	**	**	**	**	**	**	**	**	**	**	**	**
LSD 0.05	5.84	4.74	2.91	2.99	3.03	1.87	0.04	0.02	4.79	4.38	0.76	1.11
0.01	7.83	6.36	3.90	4.01	4.06	2.50	0.05	0.03	6.43	5.87	1.02	1.48
Polynomial regression												
Linear	**	**	**	**	ns	ns	**	**	**	**	**	**
Quadratic	**	**	**	**	**	**	**	**	**	**	**	**
Cubic	**	*	*	**	ns	ns	**	**	ns	ns	ns	ns
● Herbicides												
Control	075.90 d	089.28 d	22.57 d	26.81 d	68.28 d	79.55 d	0.80 d	0.89 d	064.22 d	078.97 d	23.78 d	25.45 d
Pendimethalin	095.55 c	103.96 c	29.10 c	36.71 c	72.98 c	85.99 c	0.88 c	0.97 c	073.73 c	099.51 c	26.26 c	29.38 c
Glyphosate	116.12 b	119.84 b	36.35 b	41.68 b	80.98 b	93.33 b	0.98 b	1.10 b	094.14 b	112.78 b	28.97 b	32.00 b
Pendimethalin + Glyphosate	133.00 a	132.90 a	50.83 a	57.03 a	86.43 a	98.86 a	1.07 a	1.17 a	105.37 a	128.56 a	32.73 a	34.51 a
F-Test												
LSD 0.05	**	**	**	**	**	**	**	**	**	**	**	**
0.01	5.79	5.87	2.40	2.62	2.25	1.86	0.02	0.03	4.75	6.15	0.80	0.91
Orthogonal contrast	7.65	7.75	3.17	3.46	2.98	2.45	0.03	0.04	6.28	8.13	1.06	1.20
Control vs Others												
Pendi. vs Pendi. + Glyphosate	**	**	**	**	**	**	**	**	**	**	**	**
Gly. vs Pendi. + Glyphosate	**	**	**	**	**	**	**	**	**	**	**	**
	**	**	**	**	**	**	**	**	**	**	**	**

*, **, 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 Fisher's Protected L.S.D Test of Significance.

Table (2): Impacts of irrigation frequencies, hand weedings and herbicides on flowering quality indices and leaves 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).

Flowering quality characteristic (avg.)	Floret # / spike (pairs)		Quality rating [Y]		Flower index [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
• Irrigation frequencies (Days) [X]												
Two	30.96 a	33.11 a	9.39 a	9.97 a	57.33 a	53.33 a	3.51 a	3.64 a	2.64 b	2.56 b	3.17 c	2.79 b
Four	28.87 b	30.25 b	8.86 b	9.53 ab	41.41 b	41.41 b	3.48 a	3.67 a	2.64 b	2.57 b	3.27 bc	3.15 a
Six	24.75 c	27.32 c	7.92 c	8.93 b	34.78 c	38.26 c	3.52 a	3.70 a	2.65 b	2.62 b	3.42 b	3.20 a
Eight	20.19 d	23.78 d	6.01 d	6.50 c	21.86 d	26.86 d	3.60 a	3.68 a	2.82 a	2.77 a	3.60 a	3.22 a
F-Test	**	**	**	**	**	**	ns	ns	*	*	**	*
LSD 0.05	0.77	1.66	0.21	0.64	5.12	3.75	—	—	0.14	0.15	0.16	0.32
0.01	1.11	2.38	0.30	0.92	7.35	5.38	—	—	0.19	0.21	0.23	0.46
Polynomial regression												
Linear	**	**	**	**	**	**	ns	ns	*	*	**	**
Quadratic	**	ns	**	**	ns	**	ns	ns	ns	ns	ns	ns
Cubic	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
• Manual weeding (Weeks)												
Control	24.66 d	26.90 c	7.36 c	7.87 d	27.55 d	32.58 d	3.80 a	3.79 a	2.91 a	2.93 a	3.55 a	3.35 a
Four	27.37 a	30.58 a	8.61 a	9.42 a	50.83 a	65.50 a	3.28 c	3.52 b	2.43 c	2.35 c	3.25 b	2.85 c
Eight	26.69 b	28.93 b	8.21 b	9.11 b	42.17 b	52.37 b	3.56 b	3.65 ab	2.65 b	2.47 c	3.28 b	3.06 b
Twelve	26.06 c	28.05 bc	8.01 b	8.53 c	34.85 c	45.89 c	3.47 b	3.73 a	2.77 ab	2.77 b	3.38 ab	3.11 b
F-Test	**	**	**	**	**	**	**	**	**	**	**	**
LSD 0.05	0.60	1.25	0.27	0.28	3.99	4.70	0.10	0.15	0.14	0.15	0.18	0.17
0.01	0.81	1.68	0.37	0.38	5.35	6.30	0.14	0.21	0.19	0.21	0.24	0.23
Polynomial regression												
Linear	**	**	**	**	**	**	**	ns	**	*	*	**
Quadratic	**	**	**	**	**	**	**	**	**	**	**	**
Cubic	ns	ns	ns	ns	**	**	**	ns	*	ns	ns	ns
• Herbicides												
Control	23.69 d	24.73 d	6.66 d	7.48 d	21.31 d	27.28 d	3.85 a	4.08 a	3.12 a	3.08 a	3.86 a	3.53 a
Pendimethalin	25.58 c	28.14 c	7.61 c	8.52 c	29.14 c	43.46 c	3.61 b	3.80 b	2.85 b	2.73 b	3.57 b	3.20 b
Glyphosate	26.81 b	29.72 b	8.66 b	9.20 b	41.93 b	49.82 b	3.40 c	3.58 c	2.61 c	2.52 c	3.22 c	2.93 c
Pendimethalin + Glyphosate	28.70 a	31.88 a	9.26 a	9.74 a	63.01 a	75.78 a	3.25 d	3.23 d	2.18 d	2.19 d	2.82 d	2.72 d
F-Test	**	**	**	**	**	**	**	**	**	**	**	**
LSD 0.05	0.49	1.31	0.26	0.28	3.45	4.33	0.12	0.12	0.14	0.14	0.15	0.13
0.01	0.65	1.72	0.34	0.37	4.55	5.71	0.16	0.16	0.19	0.18	0.20	0.18
Orthogonal contrast												
Control vs Others	**	**	**	**	**	**	**	**	**	**	**	**
Pendi. vs Pendi. + Glyphosate	**	**	**	**	**	**	**	**	**	**	**	**
Gly. vs Pendi. + Glyphosate	**	**	**	**	**	**	**	**	**	**	**	**

*, **, 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 Fisher's Protected L.S.D Test of Significance.

[Y] Quality rating was estimated, based on a scale of 1-10; 1-4= poor (short stems & poor appearance); 5-7= good (average & fair appearance); 7-10=excellent (highly marketable & superior quality).

[Z] Flower index was calculated as flowering stalk weight/stalk length x yield of flowering stalks / sub-sub-plot (3 m^{-2}), & expressed as $g/cm/3m^{-2}$.

Table (3): Second and third order mutual interactive effects of irrigation frequencies, hand weeding, and herbicides on vegitative growth cut flower yield and flowering 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.)/sub-sub-plot (3.0mm^2)	Basal leaves (#)		Cut flower yield		Stalk length (cm)		Stalk diameter (cm)		Stalk weight (g)		Spike length (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	ns	**	ns
Irrigation x Herbicides	**	**	**	**	*	**	**	**	**	**	**	ns
Weeding x Herbicides	ns	**	**	**	ns	**	**	**	**	ns	**	**
Irrigation x Weeding x Herbicides	**	**	**	**	**	**	**	**	**	**	**	**

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

Table (4): Second and third order mutual interactive effects of irrigation frequencies, hand weeding, and herbicides on flowering quality indices and leaves 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).

Flowering characteristic quality (avg.)/sub-sub-plot (3m^2)	Floret # / spike (pairs)		Quality rating		Flower index		Leaves N content (%)		Leaves P content (%)		Leaves K content (%)	
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	ns	ns	ns	ns
Irrigation x Herbicides	**	**	**	**	**	**	ns	**	*	ns	*	*
Weeding x Herbicides	**	ns	**	**	**	**	ns	*	ns	ns	ns	ns
Irrigation x Weeding x Herbicides	**	**	**	*	**	**	**	ns	ns	ns	**	ns

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

Table (5): Pearson correlation coefficients of tuberose number of basal leaves, cut flower yield, flowering characteristics and leaves nutrient content, as influenced by irrigation frequencies, manual hand weeding and herbicides, 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).

Parameters [@]	Basal leaves (#)	Cut flower yield (#)	Stalk length (cm)	Stalk diameter (cm)	Stalk weight (g)	Spike length (cm)	Floret number / spike	Quality rating	Flower index	N %	P %	K %
Basal leaves (#)	____	0.74** 0.77**	0.82** 0.79**	0.80** 0.80**	0.65** 0.66**	0.81** 0.76**	0.79** 0.65**	0.71** 0.69**	0.70** 0.72**	- 0.27** - 0.12*	- 0.35** - 0.29**	- 0.46** - 0.46**
Cut flower Yield (#)		____	0.79** 0.75**	0.78** 0.71**	0.64** 0.70**	0.78** 0.74**	0.75** 0.62**	0.68** 0.70**	0.91** 0.95**	- 0.28** - 0.34*	- 0.39** - 0.49*	- 0.55** - 0.52*
Stalk length (cm)			____	0.80** 0.79**	0.63** 0.71**	0.84** 0.84**	0.82** 0.68**	0.77** 0.74**	0.64** 0.67**	- 0.19** - 0.32*	- 0.33** - 0.49*	- 0.50** - 0.47*
Stalk diameter (cm)				____	0.63** 0.70**	0.78** 0.78**	0.80** 0.63**	0.73** 0.63**	0.71** 0.68**	- 0.25** - 0.31*	- 0.31** - 0.41*	- 0.47** - 0.47*
Stalk weight (g)					____	0.61** 0.72**	0.60** 0.85**	0.60** 0.63**	0.82** 0.82**	- 0.39** - 0.33*	- 0.43** - 0.51*	- 0.53** - 0.52*
Spike length (cm)						____	0.83** 0.68**	0.82** 0.78**	0.79** 0.71**	- 0.24** - 0.29*	- 0.39** - 0.47*	- 0.54** - 0.50*
Floret number / spike							____	0.80** 0.62**	0.67** 0.58**	- 0.21** - 0.33*	- 0.28** - 0.42*	- 0.44** - 0.40*
Quality rating								____	0.62** 0.66**	- 0.23** - 0.23*	- 0.34** - 0.44*	- 0.50** - 0.45*
Flower index									____	- 0.38** - 0.34*	- 0.45** - 0.51*	- 0.57** - 0.54*
N %										____	- 0.48** - 0.45*	- 0.34** - 0.34*
P %											____	- 0.49** - 0.50*
K %												____

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

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

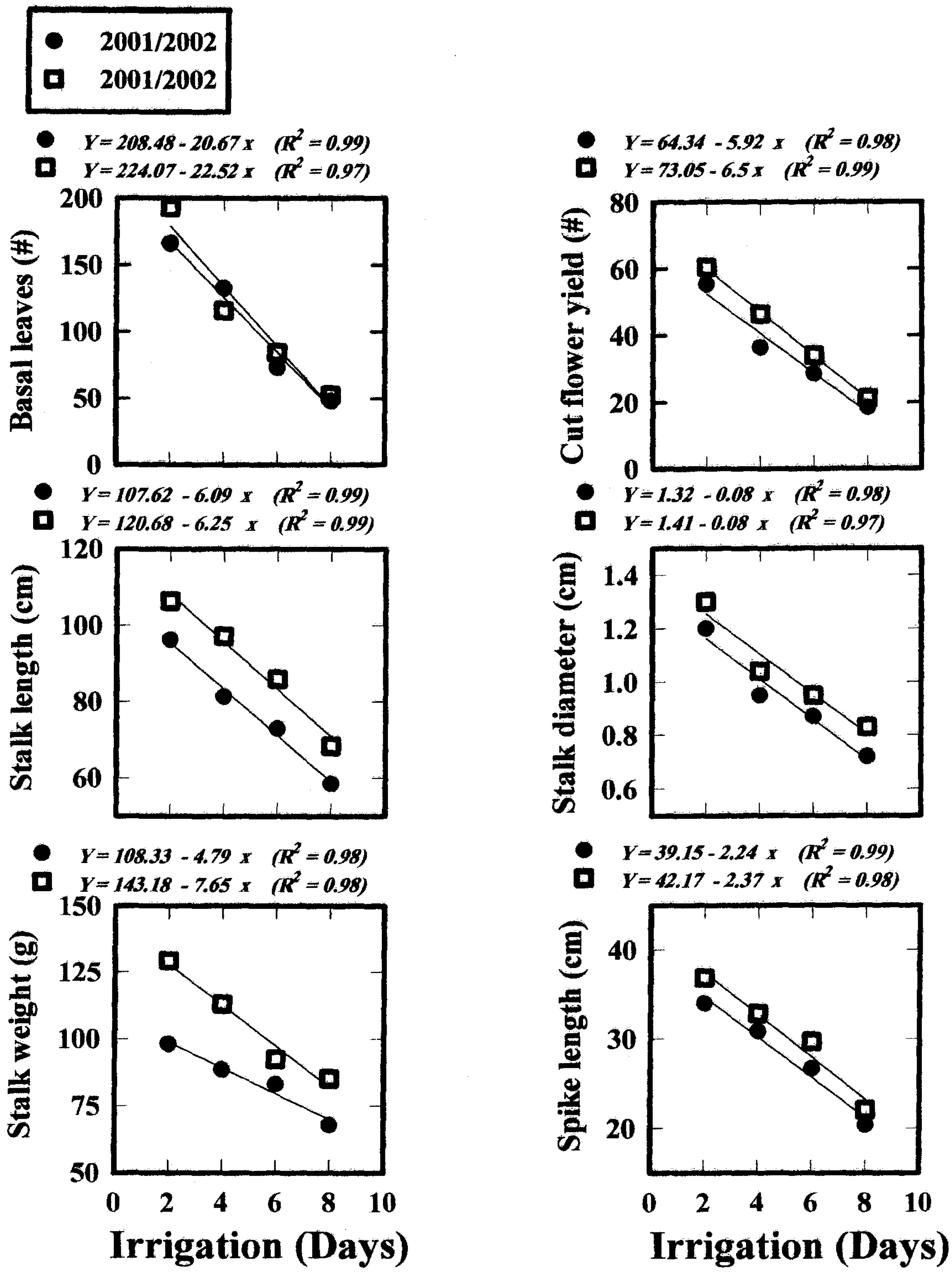

Fig. (1): First (linear) order regression analyses response curves of tuberose vegetative growth, cut flower yield, and Flowering characteristics, as function of irrigation frequencies; predicted (solid lines) & observed (symboles).

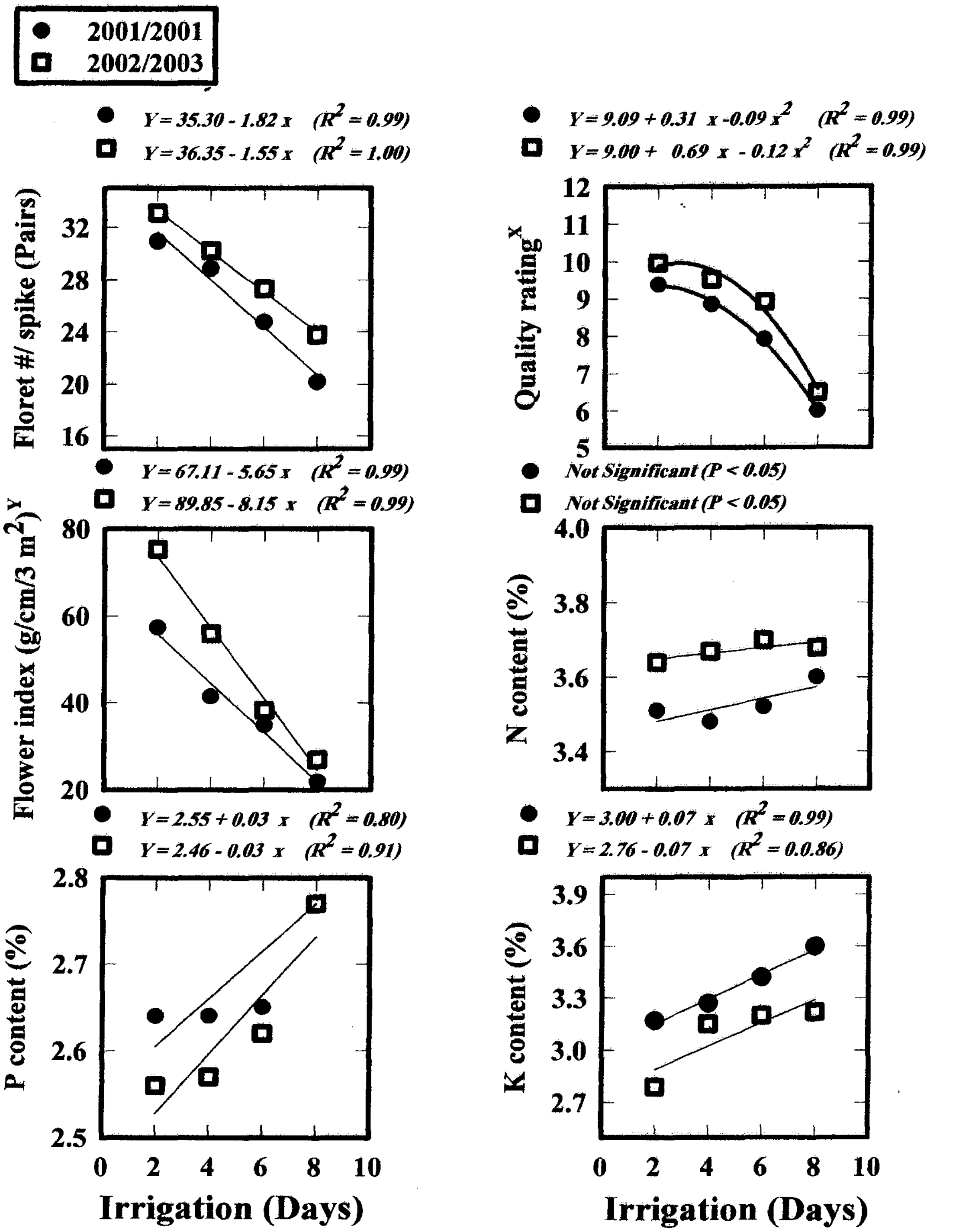

Fig. (2): First (linear) and second (quadratic) orthogonal polynomial regression analyses response curves, with best curve fitting, of tuberose flowering quality rating & indices, and leaves nutrient contents, as function of irrigation frequencies; predicted (solid Lines) & observed (symboles).

[X] Quality rating was estimated, based on a scale of 1-10; 1-4 = poor; 5-7 = fair; and 7-10 = superior quality appearance.

[Y] Flowering index was calculated as flowering stalk weight/ stalk length x yield of flowering stalks produced per sub-sub-plot (3 m^2).

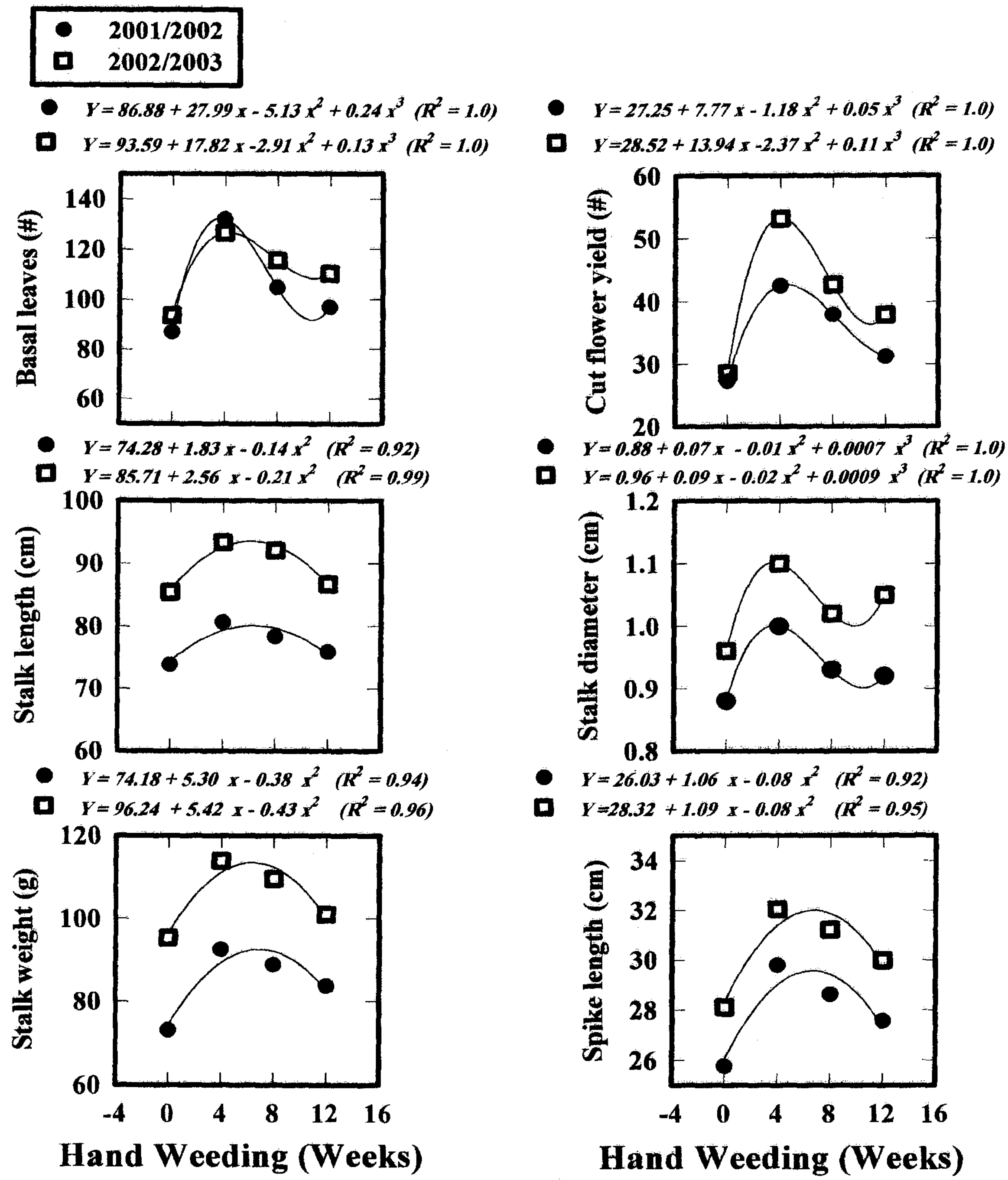

Fig. (3): Second (quadratic) and third (cubic) orders orthogonal polynomial regression analyses response curves, with best curve fitting, of tuberose vegetative growth, cut flower yield and flowering characteristics, as function of manual hand weeding; predicted (solid lines) & observed (symboles).

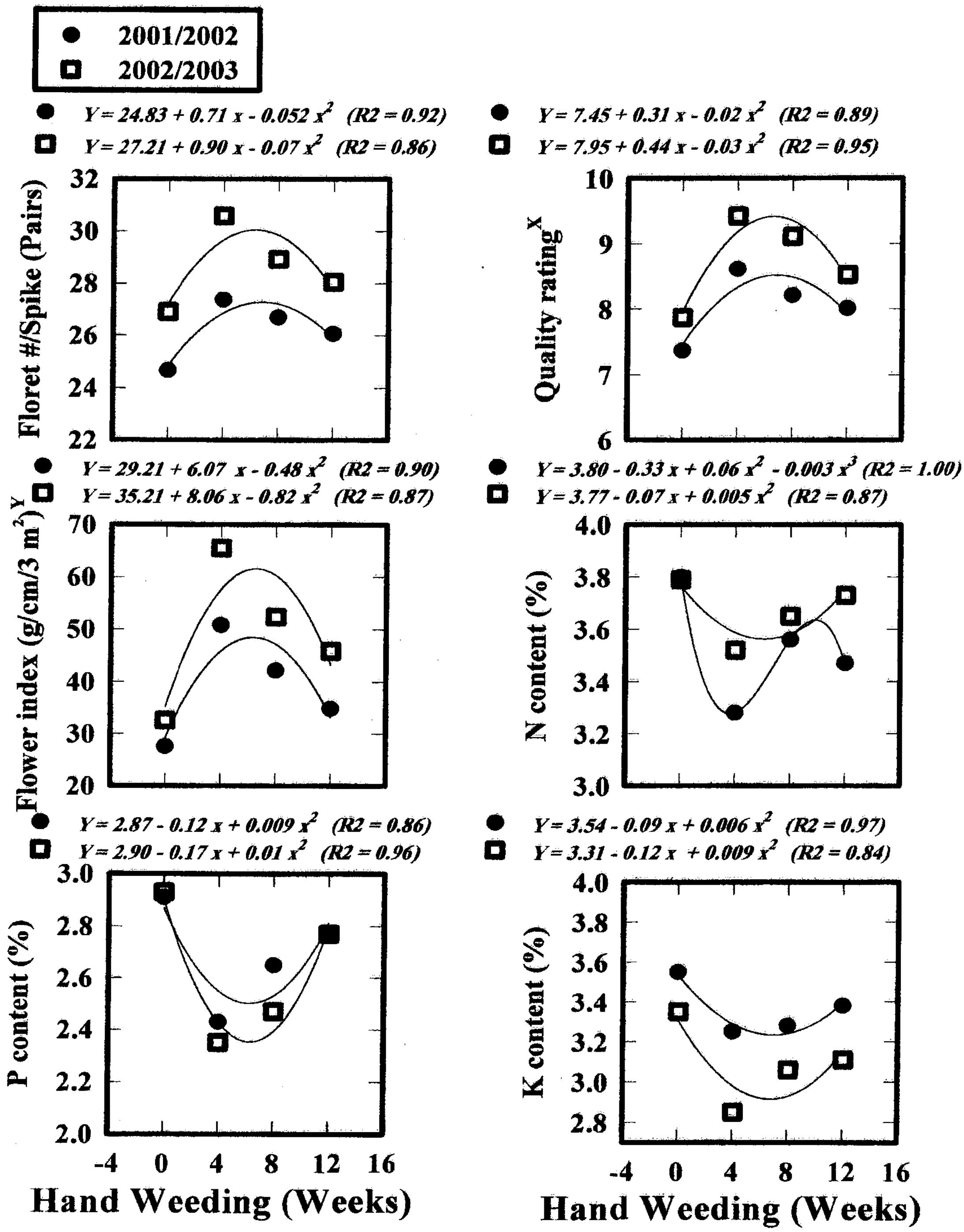

Fig. (4): Second (quadratic) and third (cubic) orders orthogonal polynomial regression analyses response curves, with best curve fitting, of tuberose flowering quality indices and nutrient contents in leaves, as functions of manual hand weeding; predicted (solid lines) & observed (symboles).

[X] *Quality rating was estimated, based on a scale of 1-10; 1-4 = poor; 5-7 = fair; and 7-10 = superior quality appearance.*

[Y] *Flowering index was calculated as flowering stalk weight/ stalk length x yield of flowering stalks produced per sub-sub-plot (3 m^2).*

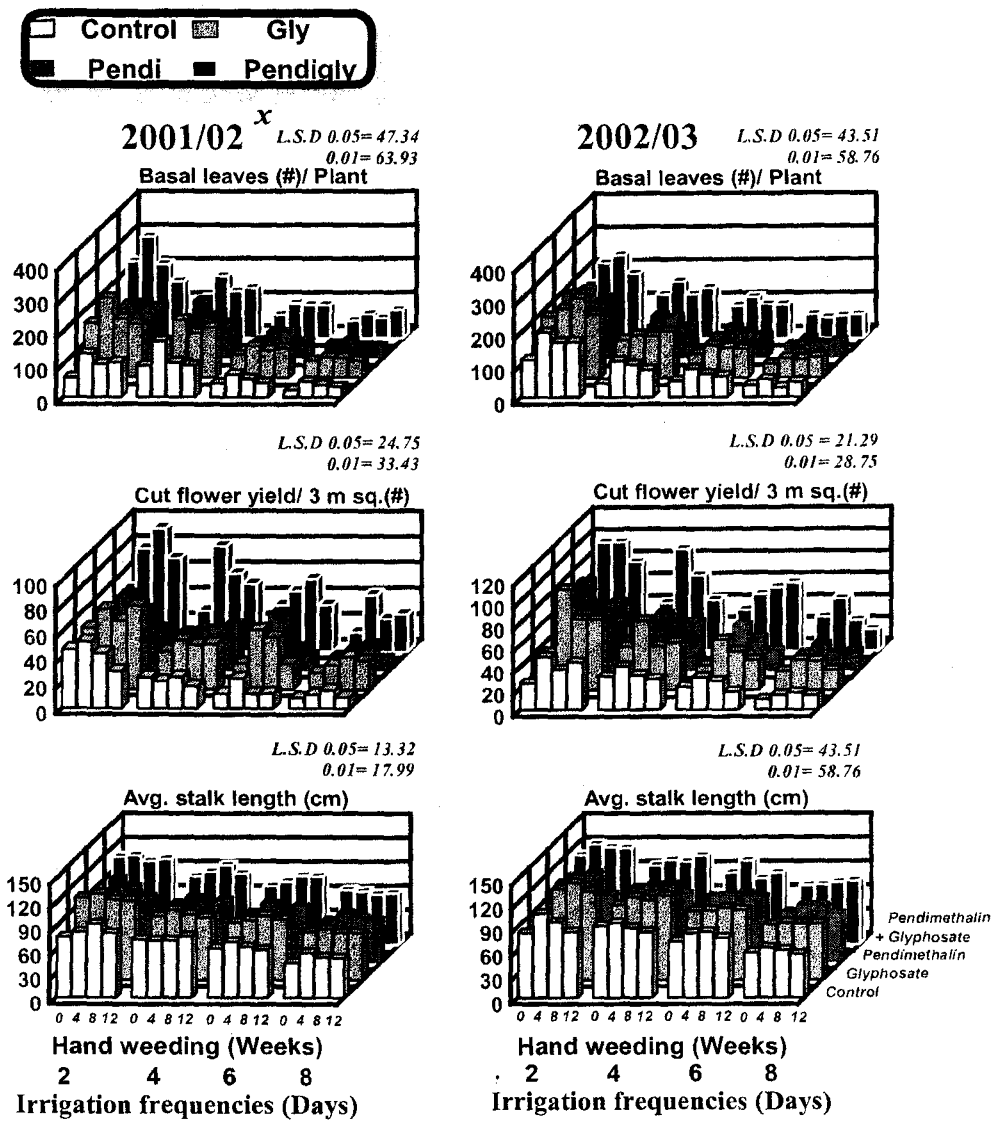

Fig. (5): Tuberose number of basal leaves/ plant, cut flower yield/ 3 m^2, and average stalk length, as influenced by the mutual interactive effects of irrigation frequencies, manual hand weeding and herbicides, during the 2001/02 and 2002/03 growing seasons, at Hada AL-Sham's Agricultural Experiment Station (Makkah AL-Mokaramah Area, KSA).

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

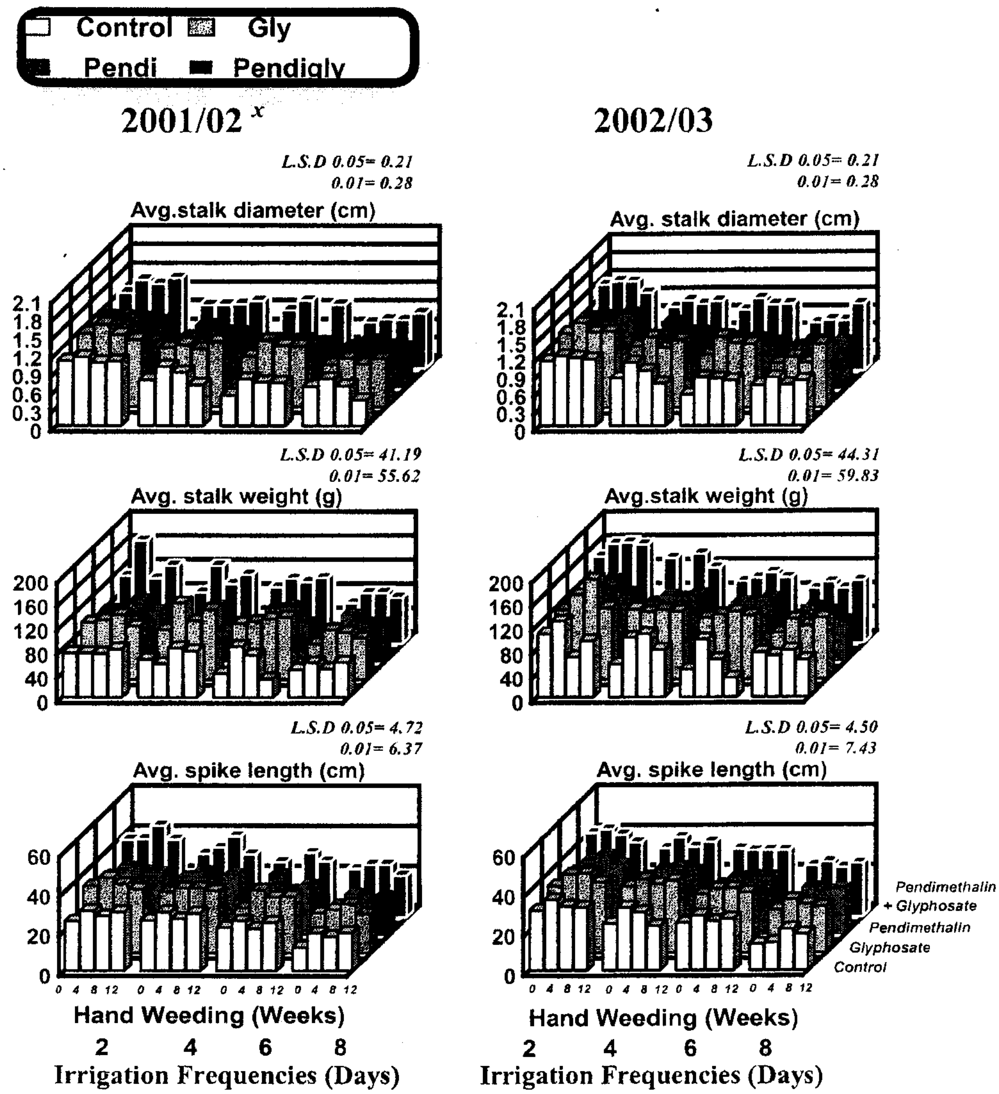

Fig. (6): Average stalk diameter, stalk Weight and average spike length as influenced by the mutual interactive effects of irrigation frequencies, manual hand weeding and herbicides, during the 2001/02 and 2002/03 growing seasons, at Hada AL-Sham's Agricultural Experiment Station (Makkah AL-Mokaramah Area, KSA).

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

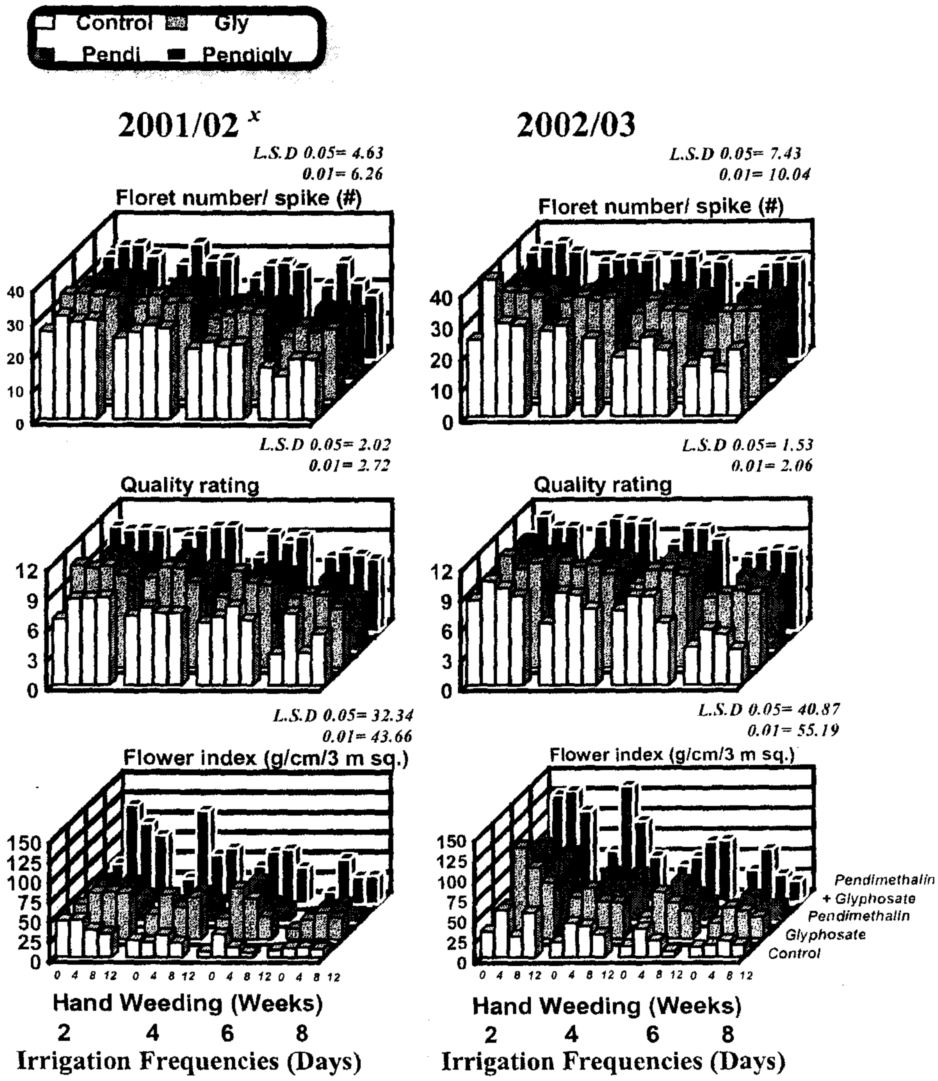

Fig. (7): Average flower number per spike, flowering stalk quality rating and flower index per sub-sub-plot as influenced by the mutual interactive effects of irrigation frequencies, manual hand weeding and herbicides, during the 2001/02 and 2002/03 growing seasons, at Hada AL-Sham's Agricultural Experiment Station (Makkah AL-Mokaramah Area, KSA).

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

CONCLUSION AND RECOMMENDATIONS

Conclusion and recommendations deduced, pertaining the concurrent investigation may indicate the following points:

- Irrigation & watering, in field grown tuberoses, is extremely indispensable, particularly under the harsh environmental conditions prevailing, in the Saudi Arabian Western Region Arid Zone.
- Tuberose plants, grown outdoors in the Western Region of Saudi Arabia, perform well, especially when frequently irrigated every two and/or four days, and it shouldn't be subjected to drought and/or water stress.
- Irrigation water is considered as a critical limiting factor, for tuberose growth and development, under the Saudi Arabian Arid Zone conditions, particularly when tuberose plants develop shallow-fibrous root system, just directly underneath growing clumps.
- Weed control, in field grown tuberoses, eliminating or at least minimizing weed/tuberose competitions, is very important, especially under furrow irrigation system, in the Western Region, in favor tuberose vegetative growth, cut flower yield and quality indices.
- Manual hand weeding, under the Saudi Arabian Western Region Arid Zone Conditions, is laborious, backbreaking and time consuming, particularly under high temperature exceeding 40 °C, most of the year round, and can be substituted by using herbicides, as an excellent, efficient, easier and cheaper alternative, weed control approach.
- Preemergence (pendimethalin) as well as postemergence (glyphosate) herbicides are very effective and efficient, in controlling weeds, and improving tuberose growth and development, especially, when they applied together.
- Pendimethalin plus glyphosate, at any level of weeding, but irrigated frequently every two and/or four days considerably improve tuberose vegetative growth, cut flower yield and quality characteristics.
- Vegetative growth performance of tuberose plants may be used as an indicator for predictable cut flower yield and/or quality indices, in field grown tuberoses.

ACKNOWLEDGEMENTS

This investigation is a part of a research project, for ameliorating tuberose, as a new floricultural crop, in the Western Region of Saudi Arabia. The authors' wishes to extend sincere thanks, appreciations, and gratitude to King Abdul-Aziz University Research Committee Counseling, for supporting this research project and funding these investigations.

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الملخص العربي

تأثيرات تكرارات الرى ومقاومة الحشائش في حقول التيوبروز بالمنطقة الغربية للمملكة العربية السعودية : II . النمو الخضري ، المحصول الزهري ، مواصفات الشماريخ الزهرية ، صفات الجودة ومحتوى الأوراق من النتروجين والفوسفور والبوتاسيوم

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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 } ومدى تأثير ذلك على النمو الخضري ، المحصول الزهري ومواصفات الشماريخ الزهرية ، صفات الجودة ، ومحتوى الأوراق من النتروجين والفوسفور والبوتاسيوم، تحت ظروف المنطقة الغربية للمملكة العربية السعودية ، خلال موسمى ٢٠٠١/٢٠٠٢ و ٢٠٠٢ / ٢٠٠٣ ، وكانت أهم النتائج كالتالي:

- أدت مناوبة الرى كل يومين أو أربعة أيام إلى زيادة معنوية لعدد الأوراق القاعدية ، والمحصول الزهري وكذلك طول الشمراخ الزهري وقطره ووزنه وأيضا طول الجزء المزهر على الشمراخ ، وذلك بالمقارنة باستخدام الرى كل ستة أو ثمانية أيام ، في كلا الموسمين . كما أدت هذه المعاملة أيضا إلى زيادة ملحوظة في عدد الزهيرات على الشمراخ (السنبلة) الزهري ، وكذلك زيادة واضحة وملحوظة في تقييم صفات الجودة للحامل الزهري وتحسن جوهري في معامل الإزهار . كان هناك أيضا انخفاض معنوي واضح في محتوى الأوراق من الفوسفور والبوتاسيوم .
- أظهرت تحاليل الإرتداد المتعدد والمتعامد وجود علاقات انحدارية خطية ، من الدرجة الأولى ، قوية جدا وسالبة بين مستويات تكرارات الرى وكل الصفات المدروسة تقريبا ، باستثناء محتوى الأوراق القاعدية من العناصر والذي بينته علاقات خطية قوية وموجبة.
- أدت المقاومة اليدوية للحشائش ، وخاصة التي كانت تتم كل أربعة أسابيع ، على تحسين النمو الخضري للتيوبروز متمثلة في زيادة كبيرة في عدد الأوراق القاعدية ، كما أدت إلى زيادة المحصول الزهري بشدة وكذلك طول الشمراخ الزهري وقطره ووزنه وكذلك طول الجزء المزهر على الحامل النوري ، وذلك مقارنة بمعاملة الكنترول أو حتى معاملات المقاومة اليدوية الأخرى . كما أدت هذه المعاملة أيضا على إنتاج أعلى عدد من الزهيرات على الحامل الزهري وأعلى مراتب الجودة التسويقية مصحوبة بأعلى معامل للإزهار . سجلت هذه المعاملة أيضا أقل النسب المئوية للعناصر الكبرى فى أوراق التيوبروز القاعدية . وجدير بالذكر أن معاملات مقاومة الحشائش يدويا ، كل ثماني أو حتى إثنى عشر إسبوعا ، حسنت النمو الخضري وزادت المحصول الزهري زيادة جوهرية ، عند المقارنة بمعاملات الكنترول .
- –بينت نتائج تحاليل الإنحدار المتعدد المتعامد وجود علاقات انحدارية قوية وموجبة ، من الدرجة الثانية ، لمعظم الصفات المدروسة ، مع ظهور علاقات قوية من الدرجة الثالثة لبعض الصفات . كما أشارت تلك التحاليل أيضا إلى وجود علاقات انحدارية قوية وسالبة من الدرجة الثانية بين مستويات المقاومة اليدوية للحشائش ومحتوى الأوراق من العناصر الغذائية .

- أدى استعمال البنديميثالين كمبيد ما قبل ظهور الحشائش مع الجليفوسات كمبيد ما بعد الظهور ، مجتمعة معا في معاملة واحدة ، إلى زيادة واضحة ومعنوية فى عدد الأوراق القاعدية وكذلك الإنتاج الزهري وصفاته وكذلك مواصفات الجودة التسويقية بدرجة عالية وكذلك انخفاض شديد في محتوى الأوراق من العناصر الغذائية موضع الدراسة ، في كلا الموسمين ، تلاه الجليفوسات ثم البنديميثالين وذلك عند المقارنة بالكنترول .
- تميزت نباتات التيوبروز النامية في قطع تجريبية عوملت بالبنديميثالين كمبيد ما قبل الظهور مع الجليفوسات كمبيد ما بعد الظهور وقومت بها الحشائش يدويا كل أربعة ، أو ثمانية أ و حتى إثنى عشر أسبوعا وتم ريها كل يومين أو أربعة أيام بأفضل نموات خضرية وأعلى محصول زهري ذو صفات جودة تسويقية عالية .
- أظهرت تحاليل بيرسون للتلازم والإرتباط في مصفوفات وجود علاقات تلازمية قوية وموجبة بين النمو الخضري (عدد الأوراق القاعدية) والمحصول الزهري ، طول الشمراخ الزهري ، قطره ، وزنه ، طول الجزء المزهر على الحامل النوري ، عدد الزهيرات على الحامل الزهري ، مواصفات الجودة وكذلك معامل الإزهار . بينما كانت هناك علاقات تلازمية قوية وسالبة بين عدد الأوراق القاعدية ومحتواها من العناصر الغذائية .