World Rural Observations

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Effects of Irrigation and Method of Fertilization on Growth and Flowering Responses of Potted Chrysanthemum

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ABSTRACT: Influences of irrigation frequency and method of fertilization on the growth and flowering of chrysanthemum grown under restricted root volume were tested. To study the effect of water regime, chrysanthemum cuttings were grown in pots and plants were irrigated regularly at 1, 2, 4 or 8 week intervals during growth period. In another pot experiment, the effect of fertilization method was tested as either foliar spray method at rates of 1.5, 3.0 and 6.0 g l^{-1}; or as fertigation application (in irrigation water) at rates of 7.5, 15 and 22.5 g l^{-1}. Both, irrigation and fertilization experiments, were conducted to observe the growth and flowering performances of chrysanthemum. The obtained results showed that plants that irrigated weekly and fertilized with 3.0 g l^{-1} as foliar spray produced the tallest plant values but flowering was inhibited. While plants irrigated at two week intervals and fertilized with 15.0 g l^{-1} as fertigation method showed better flowering and produced the highest number of flowers per plant. It is evident that the numbers of flowers were affected by both irrigation frequencies and fertilization method of application. Irrigation frequency and method of fertilization can improve the growth and flowering of chrysanthemums grown in pots with restricted volume of soil.

[Anber M. A. Hassanein. **Effects of Irrigation and Method of Fertilization on Growth and Flowering Responses of Potted Chrysanthemum**. World Rural Observ 2022;14(3):20-27]. ISSN: 1944-6543 (Print); ISSN: 1944-6551 (Online). http://www.sciencepub.net/rural. 2. doi:10.7537/marswro140321.02.

Keywords: Effect; Irrigation; Method; Fertilization; Growth; Flowering; Response; Chrysanthemum

INTRODUCTION

Chrysanthemum, family Asteraceae, is one of the most important flowering plants all over the world. It includes many species mostly native to Asia and northeastern Europe with a huge number of horticultural varieties and cultivars. Chrysanthemum is usually used as pot flowering plant for interior and exterior decoration. It is also a famous cut flowers plant at high commercial level. The vital role of water presents a great barrier preventing the cultivation of such commercially and ornamentally important plant under arid zones conditions. Fertilizer application is also an important factor affecting its growth and flowering.

The deficiency of fertilization leads to many symptoms as small leaves, light green or off-color foliage, less branches and unsatisfied flowering (Melvin and James, 2001). Plant nutrition also affects susceptibility of plants to insects and diseases. It decreased susceptibility of chrysanthemum to thrips and *Erwinia* (Schuch, 1998). Nitrogen rates affected growth of chrysanthemum, and 160 mg l^{-1} constant liquid fertilization was the best treatment (Schuch, 1998). In other work studying the effect of chemical, organic and bio-fertilization on *Chrysanthemum frutescens*, most fertilizers had a positive effect on its growth and flowering (Habib and Zaghloul, 2012). No enough information was available on the optimum fertilization regime for production of chrysanthemum.

Water stress is the most serious threat to agriculture where 40-60% of the world land suffers from drought (Bray, 1997). It is a great environmental constraint to plant growth and productivity especially in arid zones having limited water resources. So, improvement of drought tolerance must present a research priority as previously recommended by Altman (2003). Assessment of water stress tolerance is the first step toward improvement of drought tolerance in susceptible species (Farooq *et al*., 2009). It also helps in the identification of tolerant species to be cultivated in arid zones. Responses of plants under water stress are usually used for the assessment of water stress tolerance (Wang *et al*., 2001). Beach ecotypes were assessed after exposing plants to water stress under greenhouse conditions (Peuke *et al*., 2002). We previously determined pertinent indicators for the assessment of drought tolerance in pelargonium grown under *in situ* conditions (Hassanein and Dorion, 2006). We also established methods for the assessment of drought tolerance under *in vitro* conditions (Hassanein, 2010). For chrysanthemum, reduction of irrigation from sufficient to deficient decreased its growth by 25% (Schuch, 1998). In a recent research studying the effect of drip irrigation and substrate volume on *Chrysanthemum morifolium*, authors concluded that the increment of irrigation frequencies can improve growth and flowering of chrysanthemums (Taweesak *et al.*, 2014). In another recent study, Shongwe and Wahome (2014) assessed the tolerance of chrysanthemum to salinity stress by studying the effect of different levels of sodium chloride on its vegetative growth. They found a reduction of all parameters with the increment of salt concentration above 4 dS/m. However, no review was available on the assessment of chrysanthemum to water stress tolerance presenting the main environmental stress in arid zones.

From this review, it seemed important to find more information about fertilization and irrigation of chrysanthemum. So, the present work aimed to determine the optimum fertilization regime for the production of chrysanthemum and assess its tolerance to water stress. The final goal was the identification of the optimum conditions for the commercial production of chrysanthemum under arid zones conditions.

MATERIALS AND METHODS

Establishment of Study

This work was conducted under plastic house conditions at the Floriculture Experimental Farm, College of Agriculture and Veterinary Medicine, Qassim University, Saudi Arabia during two successive seasons 2014 and 2015. Two separated experiments were carried out on chrysanthemum to assess its tolerance to water stress and determine the optimum fertilization regime for its production. Plants of two months old, produced from cuttings, were used in both experiments.

Assessment of Water Stress Tolerance

This study was conducted on two months old plants individually grown in pots of 30 cm diameter filled by a mixture 3:1 of soil and organic fertilizer, under plastic house conditions. Water stress was induced by withholding water at four water stress levels or irrigation intervals for three months. Treatments included control or irrigation weekly, –20 KPa. or irrigation every 2 weeks, -40 KPa. or irrigation every 4 weeks and -80 KPa. or irrigation every 8 weeks. These levels allowed good assessment of water stress tolerance in pelargonium (Hassanein and Dorion, 2006). Each treatment contained twenty plants in four replicates. Three months after the beginning of experiment, data were collected from all studied treatments.

Study of Fertilization Regime

This study was also carried out on two months old plants grown in pots of 30 cm diameter filled by a mixture 3:1 of soil and organic fertilizer, under plastic house conditions. Seven fertilization regimes were applied to determine the optimum one for the production of chrysanthemum. Plants were fertilized with Sangral complete fertilizer (Sinclair Horticulture LTD, England). The fertilizer consists of macro elements, total nitrogen 20% N (4.4% Ammonia - 5.8% Nitrate - 9.8% Urea), Phosphorus (20% P_2O_5), Potassium (20% K_2O) , Mg (0.012%) Sulphur (0.04%) , and microelements (as ppm) Fe (70), Zn (14), Cu (13), Mn (13), B (12) and Mo (12). This fertilizer was added as spray on foliage or vegetative part using concentrated solutions of 1.5, 3 or 6 g l^{-1} or as fertigation (in irrigation water) at 7.5, 15 or 22.5 g l^{-1}. These treatments were compared to control with no fertilization. All doses were added as three equal applications at one month interval starting from the beginning of experiment. Each treatment contained twenty plants in four replicates. The other agricultural practices were carried out similarly for all treatments. Three months after the beginning of experiment, data were collected from all studied treatments.

Experimental Design and Data Collection

Both experiments were arranged in simple design with four replicates, and each one was repeated twice. The first experiment contained four treatments presenting water stress levels or irrigation intervals and the second one contained seven treatments including fertilization regimes. Twenty plants were designed for each treatment. At the end of water stress experiment, three months after the beginning of experiment, survival percentage was expressed as the number of surviving plants in relation to the number of tested plants. The increment percentages (%) in stem length and number of leaves were calculated by dividing the increment in each parameter during experiment by its original measurement at the beginning of experiment then multiplying by 100 (the parameter at the end – the parameter at the beginning / the parameter at the beginning × 100). Flowering was recorded for treatments containing plants with flowering buds or flowers at the end of experiment. For fertilization experiment, the increments percentages (%) in stem length and leaves number were calculated as explained above. Number of flowers were also recorded as the total number of flowering buds or flowers at the end of experiment, three months from beginning.

Statistical Analysis

Analysis of variance (ANOVA) was performed, on the average of the combined data of the two studied seasons, for both experiments to determine significant differences, followed by Tukey's test for the comparison of means at 5% significance level using S-Plus 6.0, Professional Release 1; 1988–2001.

RESULTS AND DISCUSSION

1. Effect of Irrigation Regimes

The effect of watering regime on survival percentages, stem length, number of leaves and flowering of chrysanthemum plants were recorded in Table (1). In this regard, the one and two week intervals had no observed effect on survival percentage of plants, since all plants survived at both irrigation regimes. On the contrary, the four week interval affected negatively survival of plants and decreased it significantly as compared to the one or two week regimes. The reduction in survival percentage under the four week treatment was about 30%. Furthermore, at the eight week interval irrigation regime all plants were died thus survival percentage was 0% at this treatment as compared with other ones (Fig. 1).

Table 1. Survival, growth and flowering of chrysanthemum under different irrigation intervals

Irrigation intervals	Survival percentage	Stem length (cm)		Leaves no.		Flowering
		Beginning	Increment %	Beginning	Increment %	
One week	100.0 a	04.0	480 a	11.0	140 a	No
Two weeks	100.0 a	10.0	200 b	19.0	50 b	Yes
Four weeks	66.7 b	06.0	150 b	10.0	30 b	No
Eight weeks	0.0 c	09.0	00 c	18.0	00 c	No

Increment % was calculated as (end-beginning/beginning*100), Means with similar letter at the same column are not significantly different at α = 0.05.

Figure 1. Growth of chrysanthemum plants under three irrigation intervals (2,4,8 weeks) compared to control (1 week).

Stem length and number of leaves per plant were also affected significantly by watering regime. In this regard, the one week interval regime was the best among all other regimes to increase stem length and number of leaves per plant (Table 1). At the end of experiment time, both parameters were increased by about 480% and 140%, respectively, as compared with initial measurements at the beginning time of the experiment. The increment%, of stem length or number of leaves, at two and four week intervals was less than that of the one week interval treatment. At eight week interval regime, no increments in both parameters were recorded since seedlings died at that treatment.

It is worth to indicate that the increment rates in stem length per week were much higher at one and two week intervals than those recorded at 4 week intervals (Fig. 2).

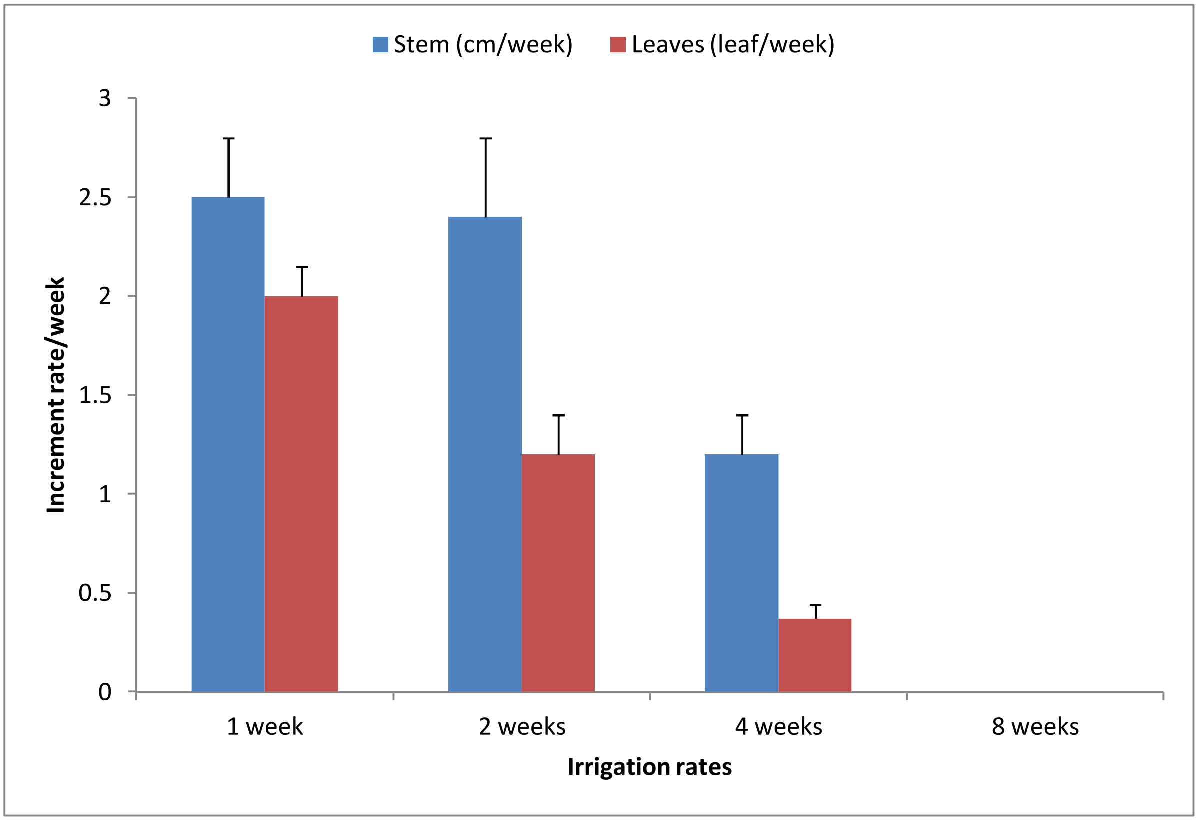

Figure 2. Effect of irrigation interval treatments on the increment rate of chrysanthemum stems and leaves/week.

It seems that the negative effect of drought conditions on leaf production was more deleterious than that on stem length. In this concern, the increment rate of stem length under two week interval treatment (2.5 cm/week) was nearly the same as that recorded at one week interval. While the increment rate of leaf number at the two week interval treatments (1.1 leaves/week) was significantly less than that of the one week interval treatment (2 leaves/week). Moreover, the four week-interval regime makes it worse either for stem length or number of leaves. Again, the effect of this treatment on leaf number increment rate (0.37 leaves/week) was more than that on stem length (1.2 cm/week). These results confirm the fact that leaf production and leaf growth are the most sensitive to water stress than any other plant organs.

Data in Fig. (1) showed also that there was linear decrease in the increment rate of leaf number per week as irrigation interval increased. In this concern, the highest increment rate/week was recorded at one week interval treatment. This finding corresponded with previous result revealed by Taweesak *et al*. (2014) who reported that increasing irrigation frequencies resulted in higher plant heights and leaf numbers/plant. However, plant heights of chrysanthemum grown in very low amount of water were lower than those grown in moderate amounts. This may be due to the stress conditions present for plants grown under restricted root volumes in the pots. Furthermore, the increment% in number of leaves was correlated to watering frequencies. This result was in agreement with other findings that found that increased substrate volume and watering frequencies led to an increase in leaf number and area of chrysanthemum (Goto *et al*., 2001).

It is well known that water deficit or periods of water shortage impact plants in a variety of ways. Drought affects how much water is available for plant use. If plants cannot tolerate lack of water various symptoms will appear. Some of these symptoms are decreasing plant height and reducing leaf production, and if drought exceeds certain limit, growth stops and foliage wilts as plants become stressed, and eventually plant death and injury are expected (Taiz and Zeiger, 2010).

With regard to the effect of watering intervals on stem length and leaf number, the different water stress treatments resulted in a gradual decrease as the stress increases. Data in the present study showed clearly that survival % at four week interval was about 67%, although under this treatment stem length and leaf production were significantly decreased. The impact of water stress as, watering interval increases, on leaf growth can be explained as a method of adaptation to the conditions of water shortage to limit the rate of transpiration (Foulkes *et al*., 2007), in order to maintain the water supply in the soil around plant roots to increase the chance of plant survival (Salisbury and Ross, 1992). In recent study, Balducci *et al*., (2014) explained the negative effect of drought particularly on growth and survival of plant seedlings as that young seedlings are more vulnerable to root embolism and stomatal closure which, in turn, affect physiological processes in plant tissues.

As for the response of plants to flower at the end of experiment time as affected by watering regime, data registered in Table (1) and illustrated in Fig. (1) indicated that all watering regimes either delayed or inhibited flowering processes except the two week interval treatment which forced plants to flower and to produce flowering buds. It seemed that the one week interval irrigation regime delayed flowering process while the 4 week interval treatments caused an inhibition of flowering process. Chrysanthemums grown at all irrigation frequencies had no flowering values except the two weeks treatment that was effective in producing flower buds (Fig. 1). This outcome accorded with the studied one in gerbera, in which flower was not influenced by very low irrigation frequency (Tsirogiannis *et al*., 2010). Moreover, this result confirms that of Maxwell and Johnson (2000) who reported that the plants experienced some stress when grown in pots under long periods of watering treatments. The role of leaf senescence as a response to adverse climatic conditions and, more specifically, on how it contributes to plant survival under drought stress is obvious in the present study. Drought induces several responses in plants including leaf senescence, which plays a major role in the survival of several species. In our study, moderate drought (two week interval treatment) may be induced leaf senescence contributes to nutrient remobilisation during stress, thus allowing the rest of the plant (i.e. the youngest leaves or flowers) to benefit from the nutrients accumulated during the life span of the leaf. This conclusion agrees with that reported by Munné-Bosch and Alegre (2004).

2. Effect of Fertilizer Applications

Data in Table (2) showed clearly that vegetative growth of chrysanthemum, as determined by stem elongation and number of leaves, was affected by fertilizer concentration and method of application. In this regard, fertilizer application as foliar spray increased growth parameters more than that as fertigation (watering with fertilizer). It was clear that stem length and number of leaves per plant increased significantly with foliar spray, as compared with control. At the end of experiment, it was found that stem length increased by about 370% or 390% at foliar spray treatments of 1.5 or 3.0 g/L, respectively, as compared with initial stem lengths measured at the beginning of experiment, while the increment% in stem length resulted from 6 g/L spray treatment (220%) was significantly less than that of control (350%). Moreover, increments % of stem length at the end of experiment with fertigation treatments were less than those recorded with foliar spray treatments or even with control value (350%). In this concern the increments % in stem length at fertigate 1, fertigate 2 and fertigate 3 treatments were about 210%, 190% and 160%, respectively (Fig. 3).

Table 2. Growth and flowering of chrysanthemum under different fertilization regimes

Fertilization regimes	Stem length (cm)		Leaves no.		Flower no.
	Beginning	Increment %	Beginning	Increment %	
Control	9.3	350 b	16.5	70 cd	1.3 cd
1.5 g l^{-1} spray	10.3	370 ab	17.8	90 c	1.8 bc
3.0 g l^{-1} spray	9.8	390 a	13.5	180 b	0.8 d
6.0 g l^{-1} spray	9.8	220 c	11.8	210 a	1.8 bc
7.5 g l^{-1} watering	12.8	210 cd	16.3	90 c	2.3 b
15.0 g l^{-1} watering	10.0	190 d	17.5	60 d	4.0 a
22.5 g l^{-1} watering	11.8	160 e	17.5	70 cd	0.0 e

Increment % was calculated as (end-beginning/beginning*100), Means with similar letter at the same column are not significantly different at $\alpha = 0.05$.

Figure 3. Chrysanthemum plants fertilized by two methods, spray (S) or watering (W) compared to control (C).

Thus, the increment rate of stem length per week at foliar spray method was generally higher than that recorded at fertigation method (Fig. 4). Number of leaves per plant was also affected by fertilizer concentration and method of application as shown in Table (2) and Fig. (4). Contrary to the effect of fertilization on stem length, there was a linear response of leaf number to fertilizer spray treatments since leaf increment % increased with the increase in foliar spray dose. The most significant increase in leaf number was recorded at 6 g/L spray treatment as compared with control. Statistical analysis, on the other side, showed that there were no significant differences between the increment % of leaf number as affected by fertigation treatments and control. Therefore, foliar spray method was more pronounced in improving number of leaves per plant than fertigation method. In this regard, the increment rate of leaf number per week at foliar spray treatments was generally higher than that recorded at fertigation method (Fig. 4).

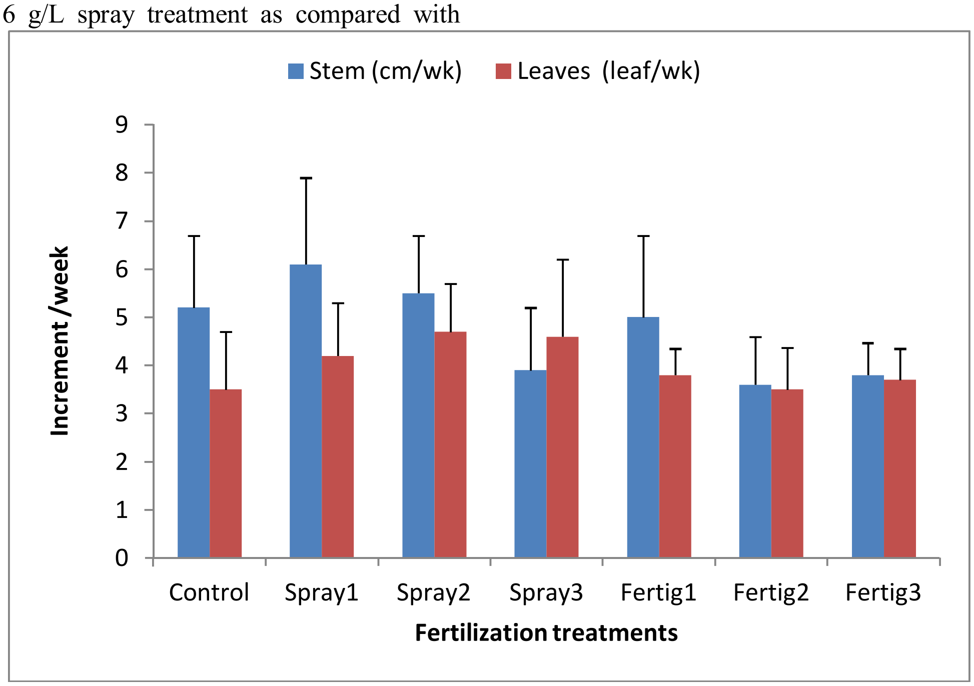

Figure 4. Effect of fertilizer treatments on the increment rate of chrysanthemum stem and leaves/week.

It seems that sufficient amounts of available nutrients inter the plant during foliar spray method ensured a greater growth and leaf production. A higher supply of nutrients in spray treatment meant statistically inconclusive growth of aboveground biomass and roots. This result concurs with studies carried out by Zhu *et al*. (2009) on *Chrysanthemum morifolium*. The lowest increment values of stem length and leaf number per plant were evident in fertigation treatments may be because this method of fertilization did not ensure an adequate supply of nutrients to the plants probably because the experiment simulated practical conditions and thus the nutrients were allowed to move far from rhizosphere or percolate down. Moreover, foliar spray treatments ensured the highest nutrient total uptake by chrysanthemums; such results were not evident with water-soluble fertilizer, according to Song *et al*. (2011).

As for the effect of fertilization treatments on the number of flowers per plant, data in the same table showed in general that fertilizer application in irrigation water (fertigation) was more pronounced in increasing the number of flowers per plant than spray method. The moderate concentration of fertilizer (15.0 g l^{-1}) as fertigation method of application was the best treatment to produce the highest number of flowers per plant as compared with other treatments. Under this treatment, flowering increased more than 200% as compared to control treatment. While 7.5 g l^{-1} caused an increase in flower number per plant by about 77% as compared with control treatment. Surprisingly, the highest concentration of fertilizer (22.5 g l^{-1}) as fertigation application caused a complete inhibition to flowering process and no flower was produced under such treatment. This result seemed logic since adequate supply of fertilizers in case of foliar spray treatments increases vegetative growth but retards or inhibits the reproductive growth and flowering. The opposite relation between vegetative growth and reproduction was discussed by Zong-min *et al*. (2012).

CONCLUSION

Results from this experiment demonstrated that irrigations of two week intervals can improve plant survival, vegetative growth and flowering characteristics such as stem length, number of leaves and number of flowers in chrysanthemum plants grown in pots under restricted root volume. The effects of fertilizer with two application methods on the vegetative growth of grown potted chrysanthemums showed that foliar spray was better than fertilizer application in irrigation water (fertigation). This may be attributable to a higher availability of nutrients to be absorbed, while fertigation method was more pronounced in increasing the number of flowers per plant. Thus, we conclude that for cultivation efficiency, an irrigation frequency of one time a week with fertilizer application of 3.0 g l^{-1}as foliar spray can be suggested for vegetative growth of chrysanthemums under restricted root volume. However, flowering would be stimulated at two week irrigation intervals and fertilization with 15.0 g l^{-1} in irrigation water.

ACKNOWLEDGEMENT

The author is very grateful and would like to express his sincere thanks towards **Prof. Dr. Ansary E. Moftah,** Agricultural Botany Dept., Faculty of Agriculture, Menoufia University, Egypt, for his support in the revision and production of this wok.

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