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Impact of Animal Manures and Chemical Fertilizers on Yield Components of Saffron (*Crocus sativus* L.)

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Abstract: Saffron (*Crocus sativus* L.) was treated with N as (urea) [$CO(NH_2)_2$, 46% N] at 50 kg ha^{-1}; P as super phosphate [$Ca(H_2PO_4)_2$, 46% P_2O_5] at 40 kg ha^{-1} alone or combination with cow deep litter manure (mixture of bedding straw + manure at 20 t ha^{-1}). Application of cow manure (M_n) plus P+N fertilizers increased spice yield (stigma dry weight) of saffron. The highest yield (0.45 g m^{-2}) was obtained with combination of M_n, P and N, while, the lowest (0.24 g m^{-2}) with control. The maximum flower fresh weight (0.99 g), with the longest stigma (30 mm) were obtained in the N+P+M_n treatment and the lowest (0.50 g) with control, respectively. The N only application increased vegetative growth (highest leaf area index = LAI), but no significant on yield. The highest LAI (2.8) was recorded in the N-only treatment, but the lowest (1.7) in the control, respectively. The highest corm multiplications rate (5.7 new corms yr^{-1}) and the lowest (2.5 new corms yr^{-1}) were recorded in the M_n treatment and the control, respectively. Application of cow manure (M_n) increased both leaf tissue mineral concentrations (DW %) and improved soil fertility (organic carbon level, soil K, Mg, Ca, N-NH_4^+ and CEC). Yield has a stronger correlation (R= 0.743) with stigma length, compared to correlation (R = 0.570) of yield with flower fresh weigh.

Key words: Soil amendment • Organic farming • Corm multiplication • Cow manure • Spice crop

INTRODUCTION

Saffron (*Crocus sativus* L.) is the most expensive spice widely used for its aroma and coloring properties [1]. It has been used as a sedative and analgesic in traditional medicinal preparations [2, 3]. Recently it has been shown to have distinct anticancer activities [4-6]. This crop has a very low harvested yield (stigmas/biomass) [7-11]. In view of that, cultivation improvement (increasing yield) in some countries of mild and dry climate is very important. This can be achieved by improving cultural methods [12, 8, 11, 13]. Saffron is a perennial crop (at least 4 to 5 years) and requires adequate amount of nutrients [10, 14]. In traditional saffron culture, no further chemical fertilizer was applied to the crop, after initially applying 15 to 30 t ha^{-1} farm yard manure at planting and field is lifted even for 4 to 5 years under non-fertilizer conditions. But, quantity and quality of spice yield production have remarkably declined in the following years [15, 16]. Application of chemical fertilizers in infertile soil increased both yield (up to 15 kg ha^{-1}) [2, 17] and increased production of daughter corms [18, 19, 14]. In Kashmir, a survey of saffron fields showed higher yields of spice were collected from younger fields that generally had a higher soil nutrient status [17] and corm production of ornamental *Crocus* species was enhanced by applying 40-50 kg N ha^{-1} [9]. Behnia, *et al*., [16] and Koocheki *et al*. [20] found that 20-80 percent of saffron yield is attributed to soil fertility (C/N ratio, available phosphorus, mineral nitrogen and exchangeable potassium).

On the other hand, some farmers, based on the type of the soil and their habits, up to 100 kg ha^{-1} ammonium phosphate prior to the first irrigation are used [18, 10], by considering that the high application of chemical fertilizers (particularly, nitrogen) promoted vegetative growth and decreased the yield [14]. Some others, traditionally have being applying a high amount of farmyard manure (animal manures, straw, compost, so on) no chemical fertilizers, as basic source of nutrients for the saffron crop [20]. Maintaining the balance between vegetative and reproductive growth (more flowers) is, however, one of the most important aim in saffron fertilizer management [18]. Increase vegetative vigor (N only application) must

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be associated with number and length stigma of flower [18]. Therefore, the hypothesis was "*a combination of chemical and organic fertilizers can be leaded to better vegetative growth and reproductive growth*". Thus, yield will be increased.

MATERIALS AND METHODS

This experiment was conducted in a Randomized Complete Block Design (RCBD) with four replications under environmental conditions of Zanjan, Iran during two years (2004 to 2005). The region, is semiarid with no summer rain and average annual temperature in the region is about 13°C; average maximum temperature, 30°C (in July); average minimum temperature, 7°C (in January); average annual rainfall 300-400 mm (rain is uncommon from May to October). Annual total chilling hours (=7.2°C) is about 850 with summer relative humidity of about 40%. Soil composition of research farm (before experiment) was: sand 60%; silt 22%; clay 18%, limestone <5%, organic carbon (OC) = 0.4%, soil pH=7.8, cation exchange capacity (CEC)= 4.2 meq100gg^{-1} and electrical conductivity (EC) = 2.1 *mS*cm^{-1}.

The treatments were: control (neither chemical, nor organic fertilizer); N only; P only; organic fertilizer (20 t ha^{-1} cow deep litter manure = M_n); N+M_n; P+M_n; N+P; and N+P+M_n. Any treatment containing N received N as urea [$CO(NH_2)_2$, 46% N] at 50 kg ha^{-1} at two times; P as super phosphate [$Ca(H_2PO_4)_2$, 46% P_2O_5] at 40 kg ha^{-1}. Cow deep litter manure (mixture of bedding straw + manure) at rate of 20 t ha^{-1} was applied once a year in the early spring. Cow manure was manually mixed into the top soil with a rake in the early spring. One cubic meter of decayed sawdust, as original bedding material, weighed 120 kg, with 180% water holding capacity. Cow deep litter manure contained approximately moisture 75%, organic carbon 28%, ash 12% (DW), pH 5.9, Ca 0.78%, K 0.5%, P 1.3%, Mg 0.4%, Cu 32 ppm, Fe 340 ppm, Mn 67 ppm and Zn 40 ppm.

Uniform saffron (*Crocus sativus* L.) corms (each 8±2 g weight) were obtained from a field in Mashhad (Iran) and they were planted in furrows formed with a plough, with corms placed about 10 cm apart along the row and about 15 cm deep, in June. The plot size was 2x5m and the distance between the rows is about 25 cm. To omit interaction between agricultural practices and fertigation, the traditional practices (manual weed control, ground irrigation, etc.) were applied similarly for all treatments. Only four to five times of irrigation was similarly applied yearly for all treatments. Weeds were controlled by hand, when needed. After a period of dormancy through the summer (rarely irrigation during summer), the corms send up their narrow leaves and begin to bud in late September and plants begin to flower. Flowering was about 15 ±2 days and flowering harvesting was done at dawn during 2 weeks at the beginning of November. Stigmas were immediately separated from flowers by hand. Following the separation of the stigmas from the flowers, stigmas were immediately dried in hot room (final products with 14±2 % moisture). Flower fresh weight (g), flower number (No. m^{-2}), stigma length (mm), stigma fresh weight (g flower^{-1}) and stigma dry weight (g m^{-2}) as yield were measured. Furthermore, leaf area index (as vegetative growth) was measured after flowering and corms were harvested in the June and the rate of corm multiplication (new corms yr^{-1}) was calculated.

Soil samples before and after experiment were collected at a depth 0-30 cm for measuring cation exchange capacity = CEC (meq100g^{-1} soil), organic carbon = OC (%), pH (H_2O), electrical conductivity = EC (*mS*cm^{-1}), N- NO_3^- (μ g/g), N-NH_4^+ (μ g/g), P (%), Ca (%), Mg (%), K (%) and Fe (ppm). Plant tissue samples also were collected for each treatment in the next year. Samples consisted of about 20 to 30 leaves. Both soil and plant samples were oven dried at 60°C for 48 hours and ground to pass through a 40 mesh screen and were analyzed for mineral status. All soil and plant samples were digested according to technique used by Anderson and Henderson [21] and atomic absorption (Varian, AA20, Australia-Swiss) was used for mineral analysis of samples. All data were subjected to analysis of variance procedures and means subjected to LSD test at P=0.05.

RESULTS

Results show that N, P and animal manure significantly (P = 0.05) increased yield parameters (stigma dry weight, flower fresh weight, stigma length and stigma fresh weight) of saffron (*Crocus sativus* L.), compared with control (no fertilizer). Stigma dry weight (as yield) was so much greater in the three-way combination treatment (N+P+M_n) than would be expected from the effects of the individual fertilizers, suggesting a synergistic effect between the organic and inorganic fertilizers. The highest average of flower fresh weight (0.99 g), with the longest stigma (30 mm) were obtained in

Table 1: Effect of N, P and cow manure on flower fresh weight, stigma length, fresh and dry weights of stigma of saffron (*Crocus sativus* L.) in the zone of Zanjan, Iran[a]

Treatment	Flower FW (g)	stigma length (mm)	stigma FW (g/flw)[1]	stigma DW (g m^{-2})[2]
control	0.5	19	0.022	0.24
N	0.7	22	0.028	0.28
P	0.7	20	0.029	0.28
M_n3	0.8	23	0.038	0.29
N+P	0.9	25	0.039	0.29
N+M_n	0.9	26	0.04	0.28
P+M_n	0.8	24	0.039	0.31
N+P+M_n	0.99	30	0.052	0.45
LSD	0.19	3.2	0.011	0.03

[a]each value is average over two years; [1]stigma fresh weight per flower (g); [2] stigma dry weight as yield (g m^{-2}); [3] M_n = 20 t h^{-1} cow manure. P = 0.05.

Table 2: Effect of N, P and cow manure on leaf area index, rate of multiplication corm and means of corm weight of saffron (*Crocus sativus* L.) in the zone of Zanjan, Iran [a]

Treatment	Flower FW (g)	stigma length (mm)	stigma FW (g/flw)[1]	stigma DW (g m^{-2})[2]
control	0.5	19	0.022	0.24
N	0.7	22	0.028	0.28
P	0.7	20	0.029	0.28
M_n[3]	0.8	23	0.038	0.29
N+P	0.9	25	0.039	0.29
N+M_n	0.9	26	0.04	0.28
P+M_n	0.8	24	0.039	0.31
N+P+M_n	0.99	30	0.052	0.45
LSD	0.19	3.2	0.011	0.03

[a]each value is average over two years; [1] corm multiplication rate; [2]number of corms m^{-2}>5 g and total weight assessed in late summer before flowering (September); [3]M_n = 20 t h^{-1} cow manure; P = 0.05

the three-way combination treatment (N+P+M_n) during experiment (Table 1). Similarly, the greatest mean of stigma fresh weight (0.052 g $flower^{-1}$) and stigma dry weight (yield = 0.45 g m^{-2}) were obtained in the three-way combination treatment (N+P+M_n). Whereas, the lowest average of yield (0.23 g m^{-2}) was recorded for control during experiment (Table 1). Flower appearance in the control treatment occurred 4-6 days later than P application treatments (data are not shown). In other words, P fertilizer leads to early flowering. While, N only application increased vegetative growth (LAI), but no significant on yield (stigma dry weight). The highest average of LAI (2.8) and the lowest (1.7) were observed in the N-only and control treatments, respectively (Table 2). The greatest average of corm multiplications rate (5.7 new corms yr^{-1}) and the lowest (2.5 new corms yr^{-1}) were obtained in the three-way combination treatment (N+P+M_n) N+P+M_n and control, respectively (Table 2). The largest (11.5 g) corms were obtained in the M_n treatment (Table 2). The highest amount of corm yield (No. corms m^{-2}>5 g) was 109 m^{-2}, which it was recorded in the N+M_n treatment (Table 2). Yield (stigma dry weight) has a stronger correlation (R^2 = 0.743) with stigma length, compared to correlation (R^2 = 0.570) of yield with flower fresh weigh (Figure 1).

Leaf mineral concentrations (DW%) slightly increased by application of N, P and cow manure, especially in the three-way combination treatment (Table 3). Leaf petiole mineral nutrient concentrations (DW%) were quite adequate for all elements and there was not observed any symptoms mineral deficiencies during growth seasons. Relationships between leaf tissue mineral concentrations and yield components were completely different for each treatment. Similarly, there were positive correlation between yield with corm

Table 3: Effect of N, P and cow manure on mineral concentration of saffron blade leaf (after harvesting of flowers) in the zone of Zanjan, Iran [a]

	N	P	K	Mg	Ca	B	Cu	Fe	Mn	Zn
Treatment	%					ppm				
control	0.64	0.54	3.09	0.37	1.98	33	28	68	189	48
N	0.87	0.55	3.6	0.46	1.84	52	12	94	195	43
P	0.63	0.85	3.82	0.39	1.95	38	14	82	153	44
M_n1	0.7	0.6	4.04	0.57	1.51	36	13	90	195	41
N+P	0.75	0.56	3.95	0.49	1.61	37	11	95	190	42
N+M_n	0.88	0.62	3.85	0.33	1.78	48	12	75	161	36
P+M_n	0.76	0.69	3.93	0.47	1.4	37	24	70	172	40
N+P+M_n	0.86	0.61	3.58	0.35	1.72	36	32	76	163	52
LSD	0.16	0.25	0.75	0.17	0.48	11	9.5	15	19	8.7

[a]each value is average over two years (2004-2005); [1] M_n = 20 t h^{-1} cow manure; LSD = 0.05.

Table 4: Effects of chemical (N as urea at 50 kg ha^{-1}, P as super phosphate at 40 kg ha^{-1}) and cow deep litter manure (20 t ha^{-1}) application on soil nutrient content and chemical properties in saffron farm during two years.*

Treatments	CEC[1](meq)	OC[2](%)	pH(H_2O)	EC[3] (mS)	NO_3^-µ g/g	NH_4^+µ g/g	P(%)	Ca(%)	Mg(%)	K(ppm)	Fe(ppm)
control	4.2	0.4	7.5	2.1	33	14	2.1	1.9	0.5	230	23
N	6.4	1.3	7.4	2.2	45	21	1.8	2.1	0.5	450	21
P	7.2	1.6	7.3	2.4	37	15	2.6	2.3	0.6	519	26
M_n[4]	14.8	3.6	7.6	3.2	39	17	2.3	2.8	0.8	620	41
N+P	6.8	1.5	7.4	2.3	41	18	2.2	2.2	0.5	485	36
N+M_n	10.6	2.5	7.5	2.7	42	19	2.1	2.5	0.6	535	29
P+M_n	11.0	2.6	7.5	2.8	38	16	2.5	2.6	0.7	570	38
N+P+M_n	14.2	3.3	11.2	3.9	61	27	3.4	3.6	0.9	720	56
LSD	2.8	0.7	0.45	0.75	8.6	5.4	0.45	0.32	0.14	125	6.4

*Each value is average over two years; [1]CEC=cation exchange capacity in meq100g^{-1} soil; [2] OC organic carbon (%); [3] EC=electrical conductivity in *mS*cm^{-1}; [4] M_n = 20 t h^{-1} cow manure; LSD=0.05.

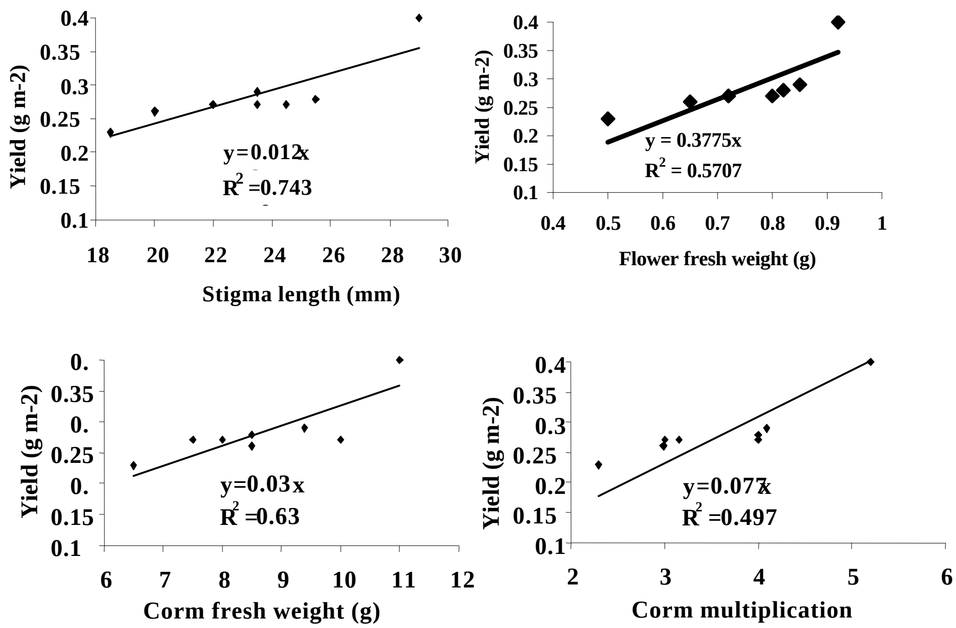

Fig. 1: Correlation between yield (stigmas dry weight, g m^{-2}) with stigma length (mm), flower fresh weight (g), corm multiplication rate (No. yr^{-1}) and corm fresh weight (g)

multiplication rate and corm fresh weight (Figure 1). Since the content of cow deep litter manure was: moisture =75%, OM =28%, ash =12% (dry weight), pH =5.9, Ca= 0.78%, K =0.5%, P=1.3%, Mg =0.4%, Cu =32 ppm, Fe =340 ppm, Mn =67 ppm and Zn =40 ppm, application of cow manure (20 t h^{-1}) significantly (P = 0.05) increased soil OC levels from 0.4% to 3.6%, soil K, Mg, Ca, N-NO_3, N-NH_4^+ and also soil CEC from 4.2 to 14.8 meq 100g^{-1} (Table 4).

DISCUSSION

This study shows the soil fertility management for saffron production can be mainly based on combination of organic fertilizer (cow manure) with chemical (N, P). Some farmers keep only their domestic animals (cow, sheep and cattle) in their saffron fields during late spring and summer. This mainly improves soil fertility, but it may can not supply all of nutrient requirements for optimum growth (reproductive) of saffron. Nevertheless, combination of animal manure (20 t ha^{-1} cow manure) with P (40 kg ha^{-1}) and N(50 kg ha^{-1}) was resulted to the highest yield and corm production (Table 1). It can be said that consistently high yield of spice obtained from an established crop has probably been assisted by the annual application of balanced fertilizers to maintain adequate soil nutrient levels [2].

Beneficial effect of nutrition on yield (stigma dry weight) performance confined to all macro and micronutrients, which provides from animal manure and plus N+P combination. A fertilizer application of N only increased mostly vegetative growth. But N combined with cow manure could be well utilized by the plants because of more nutrient availability in the soil, especially whear water is limmited in the summer. On the other hand, it can be said that the feature of saffron flower is its style, with different lengths (18-30 mm) of stigmas, which is resulted to the yield differences among treatments (Table 1). Increasing yield is due to the role of available phosphorous [in $Ca(H_2PO_4)_2$, 46% P_2O_5 and cow manure =1.3%] on the growth of flower parts. In the mean while, nitrogen can improves vegetative and reproductive growth. Nitrogen uptake was high in the first year and markedly increased in the second year. As a consequence, N increases flowering in the second year. Furthermore, this condition leaded to excellent longer period flowering. Comparison to non fertilizer conditions (control) that results in less and shorter period flowering with small stigmas. Nitrogenous fertilizer also allows a greater leaf area index (LAI) and crop growth rate (CGR). Consequently influence a significant effect on the production of daughter corms (Table 2). The largest the mother corm, the more daughter corms will be produced in the annual cycle, which increases the potential for higher yields in subsequent years.

In biology of saffron, corm nutrient reserved have considerable important, because rich nutrient conserved (larger) corms started to flowering sooner and with higher quality [14, 22]. Both vegetative and reproductive (flowering, flower parts) growth were highly dependent on nutrient requirement of plant, especially in the third and fourth year, when plants are nutrient exhausted and generally yield begin to fall due to mineral deficiency and overcrowding of corms. With good nutrition and management, crops can produce well for at least 4 years (following low yields in the year of establishment) [15, 20]. Field observation showed that application of organic fertilizers compared with chemical fertilizers caused one week earlier flower emergence [10], which emphasize on positive effect of organic fertilizer up to 50 t ha^{-1}.

These results indicated that small corms are not guaranteed to flowering during years and if these corms can produce flower in next years (which is likely), the flowering duration of saffron as a perennial crop will be decreased. The effect of corm size on its reproductive capacity and flowering showed that both the production of corms and yield of flowers were dependent on the initial size of the corm of planting [23], corm production, yields were the highest from mother corms >4 cm in diameter [12, 22], indicated that the largest corms (3.25-3.75 cm) resulted in the highest number of flowers per corm.

In general, application of animal manures in infertile sandy soil, where saffron grown, increased organic carbon (up to 4%), soil fertility, CEC and higher nutrient availability (Table 4). Slow release of nutrients from cow manure during growth period and hence low leaching of the nutrients could also be other feature for cow manure [24-26]. It must be remembered that there are less Fe and Zn available in soils with low OM and high alkaline and high pH and sustaining the level of these nutrients could be problematic. Success in using animal manure depends not only on the total amount of nutrients released and the degree of decomposition but also whether the pattern of release matches the demand of minerals by the crop and whether the manure within the decomposition can be maintained in the long-term.

CONCLUSION

It can be inferred that saffron nutrient demands could be supplied by application of enough animal manures. Evidences showed that application of adequate animal manure supplied not only nutrient requirements of plant, but also improved soil fertility. Application of organic fertilizers, as soil amendments or surface mulches, have been advocated as compatible with IAP (Integrated Agricultural Production) since fertilizer inputs can be reduced. This leaded to minimize the use of chemical fertilizers (organic system) and consistently affected quantity and quality of saffron yield.

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