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FERTILIZER SOURCE, DOSE AND PLANTING GEOMETRY EFFECTS ON OKRA SEED YIELD AND QUALITY

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ABSTRACT

Ladyfinger, also known as okra or bhindi, is a vital summer seasonal vegetable, member of the Malvaceae family. Several aspects disturb its seed production, including insufficient nutrients, which reduces the yield and quality of the seed crop. A research trial was completed at the Institute of Horticultural Sciences, University of Agriculture, Faisalabad. Various fertilizer doses (FD1=N30:P45:S02kg/acre using DAP, urea and sulfur, FD2=N30:P30kg/acre using nitrophos and FD3=N60:P60kg/acre using nitrophos) and planting geometry (plants on one side of the ridge or both sides of the ridge) were used to estimate its effect on quantity and quality of okra seed. Results revealed that application of FD3 (N60:P60kg/acre) recorded higher yield attributes in terms of plant height (121.2cm), pods per plant (14.4), pod yield per plant (59.4g), seed yield per plant (36.0g), seed yield per plot (3.0kg) and weight of 100-seeds (5.2g). While, FD1 (N30:P45:S02kg/acre) gave the highest values for seed viability (88.3%), mean emergence rate (3.7), radicle length (5.9cm), plumule length (5.4cm), seedling length (10.2cm), seedlings fresh weight (3.8g) and vigor index of seedlings (894.5). We obtained maximum side branches (7.2) from fertilizer treatment FD2 (N30:P30kg/acre). Planting geometry PG2 (plants on both sides of the ridge) produced maximum plant height (122.2cm), side branches (6.8), seed yield per plot (3.3kg), 100-seeds weight (5.4g), seed viability (91.4%), radicle length (5.6cm), seedlings fresh weight (3.6g) and vigor index of seedlings (878.5). Results indicated that N30:P30 kg/acre using nitrophos produced highest quality seed yield of okra with high seed quality in terms of 100-seeds weight and vigor index.

Keywords: *Abelmoschus esculentus*, Fertilizer, Planting geometry, Seed yield, Vigor index

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1. INTRODUCTION

Okra (*Abelmoschus esculentus* L.) most commonly identified by lady finger, bhindi, gumbo, ochre, and okro in several parts of the world, being part of family Malvaceae is nutritious, fast growing summer vegetable and an annual crop (Osawaru et al. 2011). Okra originated in Asia and Africa. In twelfth century, AD Egyptians cultivated okra for the first time (Thompson and Kelly 1979; Kumar and Singh 2015). Now, it is broadly cultivated in warmer areas of temperate regions, in tropical and subtropical zones (Farinde et al. 2007; Khandaker et al. 2017). It is successfully cultivated in many countries like China, Cyprus, South Africa, Brazil, Thailand, Caribbean and Egypt (Purseglove 1968). India is the largest producer that is growing okra approximately 11.91 tons/ha from an area of 514 thousand hectares (FAOSTAT 2018).

In Pakistan, plain regions of Sindh and Punjab are producing okra (Anwar et al. 2011). Okra is cultivated twice in a year, the first crop is cultivated from mid-February to end of the March while, second crop is cultivated in June and July.

In Pakistan okra is cultivated on an area of 15.7 thousand hectares with yield of 7.6 tons/ha. Highest yield of 11.8 tons/ha from an area of 5.9 thousand hectares is recorded in Punjab followed by Sindh with yield of 3.9 tons/ha over an area of 4.9 thousand hectares. In KPK and Balochistan, production of okra is relatively low than Punjab and Sindh. In KPK, area under okra cultivation is 2.36 thousand hectares with a yield of 6.4 tons/ha similarly, in Balochistan the average yield of okra is 6.19 tons/ha from an area of 2.4 thousand hectares (MNFSR 2018-2019). However, poor crop growth is observed in Pakistan than other states around the world (Chattopadhyay et al. 2011). Main reason behind poor yield in countryside is poor cultural practices, attack of certain insects, pests and absence of quality seed (Amjad et al. 2002; Rahman et al. 2013).

Usage of synthetic fertilizers has become inevitable to enhance crop yield and quality to meet the demand of food due to continuous increase in human population. Particularly, after green revolution usage of pesticides and chemical fertilizers is greatly increased (Goutam et al. 2011). Health of soil, vegetable quality and uptake of nutrients has been severely affected by indiscriminate usage of synthetic fertilizers (Agrawal 2003; Baishya et al. 2017). At appropriate level the usage fertilizers cause optimistic effects on yields of crop (Akande et al. 2010; Zaman et al. 2018). In growth of crop, P and N play important role and no element can be perform other element's specific function in plant (Khandaker et al. 2017). Therefore, now a day's synthetic fertilizer application has become mandatory to get maximum yield of crop because they release nutrients rapidly (Adepetu and Corey 1975; Jayasinghe et al. 2019). Phosphorus is main element that forms adenosine mono, di and triphosphate (AMP, ADP, and ATP) that are high energy compounds in plants, hence improve yield by performing main role in photosynthesis. In soils of tropical and temperate areas, phosphorous deficiency causes severe effects on plant growth (Akinrinde and Adigun 2005). N is the mandatory element for nutrition of plant because plants lift it up in relatively higher amounts than other elements. Appropriate supply of N to soil for crop growth improves, vegetative growth, cell division and photosynthesis in plants, consequently more flowers and fruits are produced. The deficiency of N in soil make soil less productive. Low fertility status of soil leads to poor growth of plants (Sharma and Yadav 1996).

One of great limitations faced by small okra growers is less yield for which many factors can be responsible, among which an important factor is inappropriate spacing between plants. Okra yield per unit area was increased by increasing plant population till a specific limit, beyond this limit, yield was decreased due to impediments of environmental resources compulsory for plant growth (Amjad et al. 2002).

Although fertilizers have great potential for growth improvement, but their application has to be planned sensibly in terms of optimal concentration, stage of application, species specificity and seasons. Therefore, keeping in view the importance of these two factors a field trial was performed to check the effects of various levels of DAP, urea, nitrophos and sulfur and planting geometry on okra seed production and quality.

2. MATERIALS AND METHODS

The present study was conducted in vegetable research area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad during March 2019. Soil type was sandy loam. The trial was carried out in a field of area of 6.4 Marla (1742.4sq. feet). Area of each experimental unit was 150sq. ft. Two factors experiment was laid out in split plot design. First factor was fertilizer dose and its source. In this factor three treatments FD1 (Nitrogen:Phosphorus:Sulfur) (30:45:02kg/acre), FD2 (Nitrogen:Phosphorous) (30:30kg/acre) and FD3 (Nitrogen:Phosphorus) (60-60kg/acre) were applied. In FD1 source of phosphorus and nitrogen was DAP and urea, respectively, while in FD2 and FD3 nitrophos was used as source of nitrogen and phosphorus. Second factor observed was planting geometry. Plants were grown in two planting geometries, PG1 = Single row per ridge and PG2 = Double row per ridge. Sowing was done manually on one or both sides of the ridges using the Sabz Pari cultivar of okra, using 2 seeds per hill, while maintaining 1ft P × P and 2.5ft R × R distance, respectively. First irrigation was applied right after sowing of okra seeds. The crop was irrigated at an interval of 5-6 days, depending on weather conditions, using furrow irrigation method. Fertilizers were applied in splits.

2.1. Data Recording

2.1.1. Growth Related Traits: Plant height was recorded before pod harvesting, from the ground level to the terminal bud, from five randomly selected plants. Branches arising from main stem were recorded from five randomly selected plants by counting the number of branches at the ends of the growing season before harvesting and mean values were calculated for data presentation.

2.1.2. Yield Related Trait: Mature harvested pods were collected in polythene bags replication wise for each treatment. Then pods were counted from each bag and divided by number of plants in each replication to find number of pods per plant. Weight of total pods was divided by number of plants and average value was determined for calculation of pod weight per plant. Mean seed weight per plant was determined by dividing total seed weight by total number of plants in each experimental unit. In the same way seed yield per plot was determined.

2.1.3. Seed Quality Traits: To check out seed quality, 100 seeds per replication of each treatment were sown in a media of a mixture of peat moss + rice ash + press mud in 72 celled plug trays. After sowing, these trays were irrigated and placed in growth room at controlled temperature of 25°C. Later on irrigation was given according to the requirement. Germination data were collected on daily basis. In order to calculate 100-seed weight, 100 seeds from each experimental unit were counted by hand and weighed using electrical balance. Seed viability was assessed through germination test. Number of emerged seeds were counted on daily basis, three days after sowing for calculation of average emergence rate. A random sample of five healthy seedlings were pulled off from plug trays after 14 days of germination and their length was measured for the parameters radicle, plumule and seedling lengths. Fresh weight of seedlings in grams was taken by using weighing balance and mean was calculated. Seedlings were stored in butter papers bags and placed in drying oven for 48 hours. Dry weight of seedlings was calculated in mg. Vigor index was also checked.

2.3. Statistical Analysis

All data was subjected to statistical analysis appropriate to the design using procedure developed by Steel et al. (1997) and significant differences among treatments were evaluated by employing Tukey' s test (P≤0.05).

3. RESULTS AND DISCUSSION

3.1. Growth Parameters

Data revealed that plant height increased gradually with the spike in level of applied fertilizer. Treatment FD3 (N:P=60:60kg/acre) produced maximum height (121.2cm) in plants (Table 1). While the lowest plant height (114.2cm) was observed in plants that were given treatment FD1 (N:P:S=30:45:02kg/acre) and it was found statistically similar with treatment FD2 (N30:P30kg/acre) (114.4cm). While the lowest plant height (114.2cm) was observed in plants that were given treatment FD1 (N:P:S=30:45:02kg/acre) and it was found statistically similar with treatment FD2 (N30:P30kg/acre) (114.4cm). Data indicated that maximum (7.2) lateral branches were observed in plants that were given treatment FD2 (N30:P30kg/acre). Whereas application of treatment FD3 (N60:P60kg/acre) produced minimum (4.6) lateral branches in plants.

In case of plant population effect, more height (122.1cm) was recorded for plants (Table 1) that were grown on both sides of ridge (PG2) as compared to plants that were grown on one side of ridge (PG1) (111.1cm). Previously, Gbaraneh (2018) found that plants spaced at 50cm × 30cm (close spacing) significantly enhanced plant height as compared to plants spaced at 50cm × 50cm (wider spacing). This finding was in agreement with our findings of greater plant height (122.1cm) by plants on both sides of ridge (PG2). Maximum (6.8) lateral branches were produced in plants that were spaced closely or planted on both sides of ridge (PG2) compared with PG1 (plants on one side of ridge) in which there was less plant population (5.2). These results were also in contradiction with conclusions of Saha et al. (2005) who stated that broader intra-row spacing (40cm) produced more lateral branches in contrast with side branches formed from a narrow intra–row spacing (20cm).

Table 1: Effect of fertilizers and planting geometry on growth and yield attributes of okra

Treatments	Plant height (cm)	Side branches	No. of pods/plant	Weight of pods/plant (g)	Seed yield/plant (g)	Seed yield/plot (kg)	Weight of 100-seeds (g)
Fertilizer doses (FD) (kg/acre)							
FD1 (N30:P45:S02)	114.2±1.64b	6.1±0.19b	9.1±0.83b	45.7±1.27b	24.0±1.35c	2.2±0.11c	5.10±0.23b
FD2 (N30:P30)	114.4±1.68b	7.2±0.20a	9.7±0.90b	45.9±4.71b	30.9±2.03b	2.7±0.19b	5.13±0.26ab
FD3 (N60:P60)	121.2±1.71a	4.6±0.05c	14.4±1.76a	59.4±6.10a	36.0±0.39a	3.0±0.03a	5.20±0.28a
PG (Planting geometry)							
PG1	111.1±5.28b	5.2±0.29b	13.3±2.51a	73.9±8.93a	32.6±6.18a	1.9±0.37b	4.90±0.18b
PG2	122.1±1.21a	6.8±0.27a	8.8±0.86b	26.8±0.50b	28.1±1.49b	3.3±0.18a	5.40±0.33a

PG1: Plants on one side of ridge; PG2: Plants on both sides of ridge. Values (mean±SE) bearing different alphabets in a column under specific treatment differ significantly (P<0.05).

3.2. Quantity Parameters (Yield parameters)

When plants were fertilized with treatment FD3 (N60:P60kg/acre) greater pods per plant (14.4), weight of pods per plant (59.4g), seed weight per plant (36.0g) and seed yield per plot (3.0kg) was obtained. Plants who were under application of FD1 (N30:P45:S02kg/acre) formed low weight of pods per plant (45.7g) and pods per plant (9.1) that was statistically similar to results (9.7) of FD2 (N30:P30kg/acre). Similarly, lower level of nitrogen and phosphorous along with sulfur N30:P45:S02kg/acre (FD1) gave less (24.0g) seed weight per plant and poor (2.2kg) seed yield per plot (Table 1)

If we see back in the times same conclusion was drawn by Meena and Bhati (2016) who found the highest number of pods per plant in okra by applying NPK at 90:60:90kg/ha. These results were also in line with conclusions of Khandaker et al. (2017) who stated that the highest number of pods per plant in okra by applying NPK at highest rate.

Our results were similar to Kumar and Singh (2015) who reported highest fresh weight of okra from the highest dose of N, i.e. 120kg/ha (~50kg/acre) that partially affirm our results. Given results showed resemblance with the results of Firoz (2009) according to which seed yield per plot (3.0kg) was increased by nitrogen fertilizer application (60kg/acre).

In case of planting geometry, PG1 (plants grown on one side of ridge) processed higher pods per plant (13.3), pod weight per plant (73.9g) and seed weight per plant (32.6g) as compared to PG2 (plants grown on both sides of ridge) from which lower values for fruit number per plant (8.8), pod weight per plant (26.8g) and seed weight per plant (28.1g) were obtained. The results proved that seed weight per plant reduced when plant population was increased.

Narrowly spaced plants (PG2) constituted greater plant density contributed highest seed yield per plot (3.3kg) in contrast with widely spaced plants (PG1) having low plant density that yielded less quantity per plot (1.9kg) (Table 1).

Previously, Chormule and Patel (2018) recorded highest seed yield for okra variety GJO by planting at 60cm x 45cm spacing compared to 45cm × 30cm and 60cm × 30cm spacing that corresponds to results of present study, i.e. more seed yield per plant due to single row of plants per ridge. Moreover, Odeleye et al. (2005) reported that okra plants grown at three plants per stand (125,000 plants ha^{-1}) produced the maximum yield (81.2%) which were in close conformity with the results of this study as more plant population in case of PG2 (plants on both sides of ridge) produced more seed yield (3.3kg) per plot.

Table 2: Effect of fertilizers and planting geometry on quality attributes of okra seeds

Treatments	Germination (%)	Emergence time (days)	Radicle length (cm)	Plumule length (cm)	Seedling length (cm)	Seedling FW (g)	Seedling DW (g)	Seedling vigor index
Fertilizer doses (FD) (kg/acre)								
FD1 (N30:P45:S02)	88.3±2.23a	3.7±0.21a	5.9±0.42a	5.4±0.35a	10.2±0.29a	3.8±0.23a	0.29±0.05a	894.5±3.92a
FD2 (N30:P30)	82.2±2.17b	2.4±0.13b	5.1±0.29b	4.7±0.27b	9.2±0.21b	2.8±0.17b	0.22±0.04b	809.7±3.75b
FD3 (N60:P60)	84.0±2.15b	2.9±0.18ab	5.4±0.34ab	5.3±0.33ab	10.0±0.26ab	3.0±0.2b	0.24±0.05ab	833.9±3.54b
Planting geometry								
PG1	78.3±2.02b	3.0±0.21a	5.3±0.25a	5.19±0.15a	9.9±0.26a	2.8±0.18b	0.21±0.03b	813.5±2.87a
PG2	91.4±2.31a	3.0±0.23a	5.6±0.29a	5.18±0.15a	9.6±0.21a	3.6±0.22a	0.29±0.07a	878.5±3.34a

PG1: Plants on one side of ridge; PG2: Plants on both sides of ridge. Values (mean±SE) bearing different alphabets in a column under specific treatment differ significantly (P<0.05).

3.3. Quality Parameters

It is evident from data that fertilizer levels significantly affected 100-seed weight. Maximum 100-seeds weight (5.2g) was recorded from plants that received higher levels of N and P, N60:P60kg/acre (FD3). While, least 100-seeds weight (5.10g) was recorded from plants that received N30:P45:S02kg/acre (FD1) and it was statistically at par with FD2 (N30:P30kg/acre) (5.13g) (Table 1). Statistical analysis showed that seed harvested from treatment N30:P45:S02kg/acre (FD1) showed greater viability (88.3%) and took more time (3.7 days) for seedling emergence while, seeds from plants fertilized with FD2 (N30:P30kg/acre) had less viability (82.2%) and acquired less time (2.4 days) for seedling emergence (Table 2). Maximum lengths for radicle (5.9cm), plumule (5.4cm) and seedling (10.2cm) were observed under fertilizer treatment FD1 (N30:P45:S02kg/acre) while, minimum lengths for radicle (5.1cm), plumule (4.7cm) and seedling (9.2cm) were recorded from fertilizer treatment FD2 (N30:P30kg/acre) (Table 2). In response to fertilizer application FD1 (N30:P45:S02kg/acre) greatest average seedling fresh weight (3.8g), average seedlings dry weight (0.29g) and vigor index of seedlings (894.5) were obtained whereas, lowest values for seedlings´ average fresh weight (2.8g), average dry weight 0.22g and vigor index (809.7) were observed from FD2 (N30:P30kg/acre).

Table 3: Interactive effect of fertilizers and planting geometry on growth and yield attributes of okra

Interaction FD × PG	Plant height (cm)	Side branches	No. of pods/plant	Weight of pods/plant (g)	Seed yield/plant (g)	Seed yield/plot (kg)	Weight of 100-seeds (g)
FD1 × PG1	112.0±1.50c	5.2±0.04cd	10.6±1.13b	65.6±1.92b	22.6±0.84e	1.3±0.05f	5.4±0.06b
FD2 × PG1	101.5±1.07d	5.7±0.05c	11.0±0.29b	64.3±3.21b	31.3±1.11b	1.8±0.06e	4.0±0.03d
FD3 × PG1	119.7±0.89abc	4.7±0.04d	18.4±0.84a	91.7±7.06a	43.9±0.43a	2.6±0.02d	5.4±0.07b
FD1 × PG2	116.4±0.41bc	7.1±0.14b	7.6±0.42b	25.8±0.69c	25.4±0.51d	3.0±0.06c	4.8±0.04c
FD2 × PG2	127.3±0.67a	8.8±0.21a	8.4±0.72b	27.4±1.88c	30.6±1.12bc	3.6±0.13a	6.2±0.11a
FD3 × PG2	122.8±0.31ab	4.6±0.04d	10.5±0.92b	27.1±0.95c	28.2±0.30c	3.3±0.03b	5.1±0.03bc

Values (mean±SE) bearing different alphabets in a column under specific treatment differ significantly (P<0.05).

El-Waraky (2014) reported that 14400 okra plants/ fed (lower planting density) formed maximum average values of 100-seeds weight and seed viability that was in contradiction to the results of this study. Sajid et al. (2012) reported non-significant effects of nitrogen and phosphorus fertilizers on seed viability of okra that opposes results of this experiment. El-Waraky (2014) indicated higher seed viability 84.5% in response to 45kg P_2O_5/fed P fertilization in contrast with 15 and 30kg P_2O_5/fed, in both seasons that partially resembles to FD1 (N30:P45:S02kg/acre) (88.3%) in this study.

In case of planting geometry, significantly highest values for 100-seed weight (5.4g), seed viability (91.4%), average seedlings fresh weight (3.6g), average seedlings dry weight (0.29g) and vigor index of seedlings (878.5) were calculated from seeds harvested from plants grown on both sides of ridge (PG2) (Table 1 and 2). Ridges where plants were grown on one side (PG1) comprising less plant density expressed minimum values for parameters i.e. 100-seed weight (4.9g), seed viability (78.3%), average seedlings fresh weight (2.8g), average seedlings dry weight (0.22g) and vigor index of seedlings (813.5). In case of vigor index both were statistically similar to each other (PG1 & PG2). Planting geometry showed non-significant effect on average emergence rate (days), radicle length, plumule length and seedling length (Table 2).

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Table 4: Interactive effect of fertilizers and planting geometry on quality attributes of okra

Interaction FD × PG	Seed viability (%)	Average emergence rate (days)	Radicle length (cm)	Plumule length(cm)	Seedling length (cm)	Average seedlings fresh weight (g)	Average seedlings dry weight (mg)	Vigor index of seedlings
FD1 × PG1	80.6±1.33d	3.2±0.23a	5.9±0.26a	5.8±0.18a	11.8±0.42a	3.2±0.24ab	0.20±0.05a	904.1±4.33a
FD2 × PG1	78.1±1.24de	2.8±0.16ab	4.2±0.11b	4.6±0.23a	8.3±0.23b	1.6±0.11c	0.15±0.02b	771.6±4.14c
FD3 × PG1	76.2±1.19e	2.9±0.18ab	5.9±0.18a	5.1±0.08a	9.8±0.29ab	3.6±0.29ab	0.21±0.06ab	764.9±4.01c
FD1 × PG2	96.0±2.39a	4.2±0.26a	5.9±0.19a	5.1±0.55a	8.7±0.30b	4.4±0.31a	0.32±0.08a	884.8±4.28b
FD2 × PG2	86.3±2.11c	2.0±0.13b	6.0±0.2a	4.9±0.28a	10.1±0.38ab	4.0±0.29a	0.30±0.06a	847.8±4.17b
FD3 × PG2	91.8±2.27b	2.9±0.19b	5.0±0.07ab	5.4±0.23a	10.1±0.39ab	2.6±0.2bc	0.22±0.05ab	902.8±4.29a

Values (mean±SE) bearing different alphabets in a column under specific treatment differ significantly (P<0.05).

3.4. Interaction

Interactive effect of fertilizer doses and planting geometry revealed significant effects on following yield attributes of okra (plant height, lateral branches, number of pods per plant, pod weight per plant, seed weight per plant, seed yield per plot (kg) and 100-seed weight). Plant height and lateral branches revealed best results (127cm) and (8.8) under combined effect of FD2 (N30:P30kg/acre) and PG2 (plants on both sides of ridge). The higher number of pods per plant (18.4), pod weight per plant (91.7g) and seed yield per plot (43.9g) was recorded with the combination of FD3 (N60:P60kg/acre) + PG1 (plants on one side of ridge). The data of seed yield per plot and 100-seeds weight indicated that the interaction effect of FD2 (N30:P30kg/acre) and PG2 (plants on both sides of ridge) was significantly higher (3.6kg) and (6.2g) than the other treatments (Table 3). While, in case of quality attributes of okra significant results were found for seed viability, radicle length, seedling length, average fresh weight of seedlings and average dry weight of seedlings. Seed viability was recorded highest (96.0%) under combined effect of FD1 (N30:P45:S02kg/acre) + PG2 (plants on both sides of ridge). Maximum radicle length (6cm) was measured under interactive effect of FD2 (N30:P30kg/acre)+PG2 (plants on both sides of ridge). Interaction of FD1(N30:P45:S02kg/acre) and PG1 (plants on one side of ridge) produced maximum (11.8cm) seedling length. Average fresh and dry weight of seedlings was recorded best (4.4g and 0.32g) under cumulative effect of FD1 (N30:P45:S02kg/acre) + PG2 (plants on both sides of ridge) (Table 4).

Conclusion

Application of N30:P30kg/acre using nitorphos to okra seed crop grown on both sides of ridges can give higher seed yield of good quality compared to N30:P45:S02kg/acre using DAP. But further increase in fertilizer dose, i.e., N60:P60kg/acre did not increase yield, although slightly improved seed vigor. So, for getting higher benefit: cost ratio, N30:P30kg/acre using nitrophos is recommended for okra seed production.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Contribution of Authors

KZ and SR conceived, designed and supervised this experiment. SR conducted experiment. YM performed statistical analysis. KZ prepared the manuscript draft. KYA revised the draft. AN cross-checked statistical analysis. All authors approved the final version of manuscript.

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