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Effect of raw (un-composted) and composted organic waste material on growth and yield of maize (*Zea mays* L.)

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Abstract

Fruit and vegetable wastes (FVW) having a high C: N ratio, if applied as such to agricultural soils may affect the availability of N to crops due to soil N immobilization during their decomposition. Composted organic wastes having narrow C: N ratio are highly regarded for their effectiveness for improving crop yields. Pot and field experiments were conducted on a sandy clay loam soil to compare the effectiveness of raw and composted FVW for improving growth and yield of maize (Zea mays L.). The composted FVW was enriched with 44 kg N (25% of full dose of N fertilizer) while the same amount of N was directly applied to soil in case of raw organic waste application. Composted or raw organic waste materials were tested @ 300-500 kg ha^{-1}*. Recommended rates of P and K were applied to all treatments. Results of both pot and field trials revealed a superiority of N-enriched composted organic material over the raw organic waste supplemented with N fertilizer and caused significant improvement in growth, yield and nutrient uptakes of maize. Results imply that organic waste could be composted into value added soil amendment by enriching/blending it with N to enhance efficiency of N fertilizer. Moreover, composting of organic wastes using this technology could also reduce their potential hazard to the environment.*

Key words: raw/composted organic waste, N fertilizer, maize

Introduction

Application of organic wastes to agricultural lands has received considerable attention in recent years because of the cost and environmental problems associated with their disposal. However, application of these organic wastes as such into the fields has many limitations, out of them wider C:N ratio is most critical for N availability to plants. It has been established that N availability can be a limiting factor for soil microorganisms responsible for decomposition of organic material (Mary *et al*., 1996). When organic materials having wide C:N ratio undergo microbial decomposition, the microorganisms can become N limited (Kay and Hart, 1997). Additional N can come from mineral N (Blackmer and Green, 1995) or added N fertilizer (Green *et al*., 1995) thus availability of applied N to plants is reduced which ultimately results in low crop yields.

Composting is a cost effective and environment friendly way of waste disposal (Hotink and Fay, 1986; Millner *et al*., 1998). It is a process in which organic waste materials are biologically converted into amorphous and stable humus like substances (under conditions of optimum temperature, moisture and aeration) that can be handled, stored and applied without any environmental impacts (Gallardo-Larva and Nogales, 1987; Millner *et al*., 1998). Finished compost is generally more concentrated in nutrients, narrow in C: N ratio and also effectively free from other un-desirable characteristics (Zia *et al*., 2003). The quality of compost can be improved through its enrichment with urea (N) fertilizer during composting or blending of urea fertilizer with ready compost (Banger *et al*., 1988; Mishra, 1992). However, incorporation of appropriate rate of urea-N can reduce the quantity of applied organic waste substantially. Moreover, whenever organic material containing high amount of nitrogen is applied to the soil, less amount of the originally applied organic material is decomposed/lost thus more added to the soil (Kolay, 2000).

Information about crop production in conjunction with FVW-amended soil (raw and composted form) is not currently available. Present study is therefore focused on development of an effective soil amendment from FVW by using both composting and enrichment with nitrogen to (i) compare the effectiveness of raw/un-composted and composted FVW (ii) determine N requirement of maize on FVW amended-soils and (iii) optimum application rate of N-enriched compost to increase per unit yield of maize on sustainable basis. Contrary to conventional application of organic

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wastes in t ha^{-1}, this approach is based on using organic amendment at just 300-500 kg ha^{-1}. It could help to reduce use of chemical fertilizers without compromising per unit yield of maize. The reduction of environmental pollution due to huge piling of organic wastes is an extra benefit of this strategy.

Materials and methods

Composting of organic wastes

Fruit and vegetable wastes were collected from various locations (local fruit and vegetable market and juice shops etc.) of Faisalabad city (longitude 72°0′ and 73°45′ east and 30°30′and 32°0′north), Pakistan. Collected material was sorted out to remove stones, pieces of glass, polythene bags and other unwanted materials, if any. The sorted organic waste material was sun dried for couple of days, and then passed through a crusher to extract excessive moisture/juice. After air drying, the material was oven dried at 60°C up to 24 h. The oven dried waste material was ground into finer particles (<2.0 mm) with the help of an electric grinder. The crushed material was transferred to a locally fabricated mechanical unit (vessel of 500 kg capacity) for composting under controlled temperature and aeration (shaking at 50 rev min^{-1}). A moisture level of 40% (v/w) of the compost was maintained during the composting process. The moisture was maintained by using water as well as previously extracted juice. Temperature rose up from 30 to 70°C in the composting unit during 2nd and 3rd day of composting process and then reduced gradually to 30°C after 4th day process. Composting was done for 5 days.

Pot and field experiments on maize

Pot and field studies were conducted to compare the effect of raw (un-composted) and composted fruit and vegetable waste material on growth and yield of maize.

Composted organic material was enriched with 44 kg N (25% of full N dose); while the same rate of N fertilizer was applied directly to soil in case of raw (un-composted) organic waste material. Both raw and composted organic waste materials were applied @ 300 kg ha^{-1}. Composted organic waste material was also compared with full dose of N (175 kg ha^{-1}) fertilizer in the presence of 44 kg (25% of full dose) and 88 kg N ha^{-1} (50% of full dose).

For pot trial, the air dried and sieved (40-mesh) soil was analyzed before the filling of pots. The soil was sandy clay loam having pH, 7.7; EC_e, 2 dS m^{-1}; Organic matter, 0.65%; total nitrogen, 0.04%; available phosphorus, 8.8 mg kg^{-1} and extractable potassium 126 mg kg^{-1} soil. The pots (23 cm diameter, 26 cm height) were filled with sieved soil (12 kg soil pot^{-1}) mixed with P and K fertilizers (applied @ 100 and 50 kg ha^{-1} as single super phosphate and sulphate of potash, respectively). The P and K fertilizers were applied in all the treatments as a basal dose. Soil was thoroughly mixed with raw (un-composted) as well as composted organic waste material before filling of pots.

Hybrid maize (Corn-786) was sown (4 seeds pot^{-1}) as a test crop and plants were thinned to maintain one plant pot^{-1}. The pots were arranged randomly in net house with four replications at ambient light and temperature. The pots were kept moist near field capacity (60% WHC) by using good quality canal water (electrical conductivity = 0.03 dS m^{-1}, sodium absorption ratio = 0.26 $(mmol\ L^{-1})^{1/2}$, residual sodium carbonate = 0) meeting the irrigation quality criteria for crops (Ayers and Westcot, 1985).

In the field trial, the same hybrid variety of maize as used for pot experiment was sown keeping row to row distance of 75 cm and plant to plant distance of 25 cm in a plot size of 10 m^2. The experiment was laid out in randomized complete block design with four replications. The whole dose of P and K fertilizers was applied at the time of seed bed preparation as a basal dose in all blocks, while N was applied according to the treatments in two split doses i.e. after germination and before tassaling. Raw (un-composted) and composted organic waste materials were applied @ 300 kg ha^{-1} as a band placement along the plant rows with a drill. Canal water was used for irrigation.

Field study on maize was also carried out to determine the effect of optimum application rates of N-enriched compost (44 kg N ha^{-1}) in the presence of 88 kg N ha^{-1} (50% of full dose) on growth and yield of maize. The enriched compost was applied @ 300, 400 and 500 kg ha^{-1}. Each batch of compost (i.e. 300, 400 and 500 kg) received the same amount of N (44 kg N $batch^{-1}$). Full dose of N (175 kg ha^{-1}) was included for comparison in the trial. The hybrid variety sown and agronomic field practices followed were the same as discussed earlier.

The data were analyzed statistically (Steel and Torrie, 1980). Means were compared by Duncan's multiple range test (Duncan, 1955).

RESULTS

Pot trial

The data regarding the effect of raw and enriched compost in the presence of chemical fertilizer on the plant height, dry root weight and fresh biomass of maize are given in Table 2. It was found that application of compost enriched with 44 kg N resulted in significantly greater (7.2%) plant height of maize compared with raw organic waste material supplemented with the 44 kg N ha^{-1}. Similarly, compost enriched with 44 kg N and supplemented with 44 or 88 kg N ha^{-1} significantly increased (up to 18.2%) plant height compared with raw organic waste plus 44 kg N. Plant height recorded in case of enriched compost plus 88 kg N differed non significantly with that observed in full dose of N (175 kg N ha^{-1}). The highest root weight (60.3 g pot^{-1}) was recorded where enriched compost was applied in combination with 88 kg N ha^{-1} which was at par with full dose of N fertilizer. Next was enriched compost plus 44 kg N ha^{-1} which differed significantly with both raw as well as enriched compost treatments. The root weight recorded in response to the composted organic waste material enriched with 44 kg N was significantly greater than that obtained with the raw organic waste material supplemented with the same amount of N as used for enrichment. Like root weight, the maximum fresh biomass was also observed with the combined application of enriched compost and 88 kg N which differed non-significantly from full dose of N fertilizer. Enriched compost alone or in combination with 44 kg N showed significant increase (up to 20.6%) in fresh biomass compared with un-composted raw organic waste material supplemented with 44 kg N.

Application of enriched compost in the presence of 88 kg N produced cob yield statistically at par with that observed in case of full dose of N fertilizer (Table 2). The compost enriched with 44 kg N showed superiority over un-composted raw organic waste supplemented with 44 kg N and up to 14.3% more cob yield was observed. An increase of 30.4% over un-composted organic waste material plus 44 kg N was observed when enriched compost was further supplemented with 44 kg N. In case of grain yield a non-significant difference was observed between the combined application of enriched compost plus 88 kg N and full dose of N fertilizer. It was followed in descending order by enriched compost plus 44 kg N, enriched compost alone and raw organic waste material plus 44 kg N. The maximum 1000-grain weight was recorded where enriched compost was supplemented with 88 kg N and it had non-significant difference with full dose of N fertilizer. Enriched compost supplemented with 44 kg N improved 1000-grain weight significantly over enriched compost alone. Likewise, a significantly higher grain weight was observed with enriched compost alone over raw (un-composted) organic waste material supplemented with 44 kg N.

The uptakes of N, P and K in maize were also improved by the application of composted organic waste material in integration with chemical fertilizer (Table 3). Maximum (1.69 g pot^{-1}) N uptake was recorded by the application of enriched compost in conjunction with 88 kg N ha^{-1} which was statistically at par with the full dose of N fertilizer. Next to it was enriched compost supplemented with 44 kg N. Comparison of un-composted organic waste material supplemented with 44 kg N and composted material indicated significant increase (21.3%) in N uptake by the latter. Similarly, P uptake of maize in case of full dose of N fertilizer and enriched compost supplemented with 88 kg N was similar. Application of enriched compost caused 18.9 % increase in P uptake over un-composted raw organic waste supplemented with 44 kg N. Likewise in case of K, full dose of N fertilizer resulted in highest K uptake than all treatments except enriched compost plus half dose of N fertilizer. It was followed by the treatment where enriched compost was applied in combination with 44 kg N ha^{-1}. Enriched compost resulted in significantly higher (9.8%) K uptake than un-composted raw organic waste material supplemented with 44 kg N.

Field trials

Like the pot trial, effectiveness of composted and non-composted organic waste material was also tested under field conditions in the presence of chemical fertilizers. The maximum plant height was observed where full dose of N fertilizer was applied, however this treatment differed non-significantly with the enriched compost plus 88 kg N treatment (Table 4). Application of composted material enriched with 44 kg N was more effective in increasing plant height (by 6.7%) than raw organic waste material plus 44 kg N. Regarding the fresh biomass, all the treatments differed significantly from each other. The maximum fresh biomass was produced with the application of enriched compost plus 88 kg N fertilizer, followed by full dose of N fertilizer and enriched compost supplemented with 44 kg N. Compost enriched with 44 kg N produced significantly higher fresh biomass of maize than the un-composted organic waste material supplemented with 44 kg N ha^{-1}.

Statistically similar cob yield was obtained by enriched compost plus 88 kg N and full dose of N fertilizer. It was followed by enriched compost applied in combination with 44 kg N. Application of enriched compost caused 11.6% increase in cob yield over un-composted raw organic waste material supplemented with 44 kg N. The same trend was observed in case of grain yield as maximum grain yield was observed in case of combined application of enriched compost and 88 kg N ha^{-1} that was at par with the grain yield recorded in case of full dose of N fertilizer. Enriched compost produced significantly higher grain yield than un-composted raw organic waste material supplemented with 44 kg N fertilizer. Enriched compost supplemented with 44 kg N showed further enhancement in the grain yield compared with enriched compost without supplementary dose of N. The 1000-grain weight was also highest in case of enriched compost supplemented with 88 kg N, followed by full dose of N fertilizer. Like other parameters, 1000-grain weight was also greater with the application of compost enriched with 44 kg N than the raw organic waste material plus 44 kg N.

Effect of composted organic waste material on N, P and K uptake of maize in the presence of chemical fertilizer is summarized in Table 5. Statistically similar N uptake was observed by full dose of N fertilizer and enriched compost plus 88 kg N ha^{-1}. Enriched compost supplemented with 44 kg N had significant increasing effect over enriched compost alone. Enriched compost, however, recorded significant increase of 29.9% in N uptake compared to raw/un-composted organic supplemented 44 kg N. Similarly, P uptake observed in response to full dose of N and enriched compost plus 88 kg N differed non-significantly with each other. Significantly higher (14.9%) P uptake was recorded by the application of enriched compost than un-composted raw organic waste supplemented with 44 kg N. Supplementation of enriched compost with 44 kg N further enhanced P uptake of maize. Maximum K uptake (123 kg ha^{-1}) was resulted in response to full dose of N fertilizer that was statistically at par with K uptake of enriched compost plus 88 kg N. Application of enriched compost showed a significantly higher (18.9%) K uptake over raw organic waste material supplemented with 44 kg N.

Results of both pot and field trials indicated superiority of composted material over the raw (un-composted) with respect to promoting growth and yield as well as N, P and K uptake of maize.

Based upon the preliminary study it was found that compost enriched with 44 kg N (25% of full dose of N) showed superiority over raw (un-composted) organic material supplemented with 44 kg N ha^{-1}. A field study on maize was also conducted to determine the optimum application rates of enriched compost in the presence of supplementary doses of N fertilizer. Enriched compost (44 kg N) was applied @ 300, 400 and 500 kg ha^{-1}.

The data regarding the effect of enriched compost applied at different rates in the presence of chemical fertilizer on the plant height, fresh biomass, cob and grain yield of maize are summarized in Table 6. Overall effect of three doses (300, 400 or 500 kg ha^{-1} compost) of the enriched compost was non-significant with each other as well as with full dose of N fertilizer. Based upon the results of this study, 300 kg compost ha^{-1} was found economical for obtaining maximum maize yield.

Discussion

The study was conducted to compare the raw (un-composted) vs. composted organic wastes each enriched/supplemented with N (44 kg N ha^{-1}: 25% of full N dose). Results revealed that compost enriched/mixed with 44 kg N was superior to the raw/un-composted organic waste material supplemented with same quantity of N fertilizer (44 kg) applied directly to soil (Table 2 to 5). The raw organic waste material had wider C: N ratio (Table 1) and its direct application to soil might have caused immobilization of the applied N. Composted organic waste material (with narrow C: N ratio) enriched with 44 kg N was more effective than the raw un-composted organic waste plus 44 kg N. It is well established fact that N availability can be a limiting factor for soil microorganisms responsible for decomposition of organic material (Mary *et al*., 1996). Organic material having wider C: N ratio requires additional dose of N while undergoing microbial decomposition (Kay and Hart, 1997). The

Table 1. Nutrient composition of raw ground and composted organic waste material

Parameters[a]	Raw ground material	Finished compost
Carbon (%)	31.3	20
Nitrogen (%)	1.30	1.9
C/N ratio	24.0	10.5
Phosphorus (%)	0.18	0.24
Potassium (%)	1.20	1.55
Iron (mg kg^{-1})	520	630
Zinc (mg kg^{-1})	42.0	54.0
Manganese (mg kg^{-1})	47.0	63.0
Copper (mg kg^{-1})	1.02	1.22

[a]Carbon contents and macronutrients were determined according to the methods described by Nelson and Sommers (1996) and Ryan *et al*. (2001).

Table 2. Effect of raw (un-composted) and composted organic waste material supplemented with chemical-fertilizers on plant height, dry root weight, fresh biomass, cob and, grain yield and 1000-grain weight of maize (pot experiment, the data are average of four replicates)

Treatments[a]	Plant height (cm)	Dry root weight (g pot^{-1})	Fresh biomass (g pot^{-1})	Cob yield (g pot^{-1})	Grain yield (g pot^{-1})	1000-grain weight (g)
Urea fertilizer (175 kg N ha^{-1})	133 a[c]	57.2 ab	552 a	162 a	106 ab	225 a
Raw organic waste material supplemented with 44 kg N (25%N)	110 d	43.0 d	416 d	105 d	83 d	180 e
[b]Composted material enriched with 44 kg N (25%N)	118 c	50.5 c	462 c	120 c	92 c	191 d
Composted material enriched with 44 kg N and supplemented with 44 kg N	127 b	54.2 b	502 b	137 b	100 b	200 c
Composted material enriched with 44 kg N and supplemented with 88 kg N	130 ab	60.3 a	560 a	170 a	110 a	230 a

[a]The P and K fertilizers were applied @ 100 and 50 kg ha^{-1} respectively in all the treatments.
[b]Enriched compost (147 g N kg^{-1} compost).
[c]Values sharing similar letter(s) in a column do not differ significantly at $P < 0.05$, Duncan' s Multiple Range Test.

Table 4. Effect of raw (un-composted) and composted organic waste material supplemented with chemical fertilizers on plant height, fresh biomass, cob and, grain yield and 1000-grain weight of maize (field experiment, the data are average of four replicates)

Treatments[a]	Plant height (cm)	Fresh biomass (t ha^{-1})	Cob yield (t ha^{-1})	Grain yield (t ha^{-1})	1000-grain weight (g)
Urea fertilizer (175 kg N ha^{-1})	208 a[c]	34.0 b	14.7 a	5.8 a	286 a
Raw organic waste material supplemented with 44 kg N (25%N)	178 d	27.7 e	11.2 d	4.9 d	242 d
[b]Composted material enriched with 44 kg N (25%N)	190 c	29.3 d	12.5 c	5.2 c	253 c
Composted material enriched with 44 kg N and supplemented with 44 kg N	198 b	30.8 c	13.7 b	5.5 b	266 b
Composted material enriched with 44 kg N and supplemented with 88 kg N	203 ab	35.5 a	15.1 a	5.9 a	292 a

[a]The P and K fertilizers were applied @ 100 and 50 kg ha^{-1} respectively in all the treatments.
[b]Enriched compost (147 g N kg^{-1} compost).
[c]Values sharing similar letter(s) in a column do not differ significantly at $P < 0.05$, Duncan' s Multiple Range Test.

Table 3. Effect of raw (un-composted) and composted organic waste material supplemented with chemical fertilizers on nitrogen (N), phosphorus (P) and potassium (K) uptake of maize (pot experiment, the data are average of four replicates)

Treatments[a]	N	P	K
	(g pot^{-1})		
Urea fertilizer (175 kg N ha^{-1})	1.63 a[c]	0.59 a	1.31 a
Raw organic waste material supplemented with 44 kg N (25% N)	1.03 d	0.37 d	0.92 d
[b]Composted material enriched with 44 kg N (25% N)	1.25 c	0.44 c	1.01 c
Composted material enriched with 44 kg N and supplemented with 44 kg N	1.41 b	0.50 b	1.11 b
Composted material enriched with 44 kg N and supplemented with 88 kg N	1.69 a	0.61 a	1.27 a

[a]The P and K fertilizers were applied @ 100 and 50 kg ha^{-1} respectively in all the treatments.
[b]Enriched compost (147 g N kg^{-1} compost).
[c]Values sharing similar letter(s) in a column do not differ significantly at $P < 0.05$, Duncan's Multiple Range Test

Table 5. Effect of raw (un-composted) and composted organic waste material supplemented with chemical fertilizers on nitrogen (N), phosphorus (P) and potassium (K) uptake of maize (field experiment, the data are average of four replicates)

Treatments[a]	N	P	K
	(kg ha^{-1})		
Urea fertilizer (175 kg N ha^{-1})	128.8 a	49.2 a	123 a
Raw organic waste material supplemented with 44 kg N (25% N)	61.1 d	32.2 d	71.8 d
[b]Composted material enriched with 44 kg N (25% N)	79.4 c	37.0 c	85.4 c
Composted material enriched with 44 kg N and supplemented with 44 kg N	103.1 b	41.4 b	96.6 b
Composted material enriched with 44 kg N and supplemented with 88 kg N	132.6 a	50.8 a	121 a

[a]The P and K fertilizers were applied @ 100 and 50 kg ha^{-1} respectively in all the treatments.
[b]Enriched compost (147 g N kg^{-1} compost).
[c]Values sharing similar letter(s) in a column do not differ significantly at $P < 0.05$, Duncan' s Multiple Range Test.

Table 6. Effect of N-enriched compost applied at different rates on plant height, fresh biomass, and cob and grain yield of maize of maize (field experiment, the data are average of four replicates)

Treatments[a]	Plant height (cm)	Fresh biomass (t ha^{-1})	Cob yield (t ha^{-1})	Grain yield (t ha^{-1})
Urea fertilizer (175 kg N ha^{-1})	197 NS[b]	35.2 NS	14.9 NS	5.78 NS
N-enriched compost @ 300 kg ha^{-1} supplemented with 88 kg ha^{-1} N	194	36.1	15.3	5.83
N-enriched compost @ 400 kg ha^{-1} supplemented with 88 kg ha^{-1} N	195	36.7	15.4	5.85
N-enriched compost @ 500 kg ha^{-1} supplemented with 88 kg ha^{-1} N	199	37.0	16.0	5.92

[a]The P and K fertilizers were applied @ 100 and 50 kg ha^{-1} respectively in all the treatments.
All the three batches of compost received same amount (44 kg) of N.
[b]NS- Non-significant at $P < 0.05$, according to Duncan's Multiple Range Test.

additional N can come from soil mineral N (Blackmer and Green, 1995) or from added inorganic N fertilizer (Green *et al*., 1995) and thus could have suppressing effect on plant at early growth stages. These results are supported by Fujiwara (1987) who reported that the application of well decomposed organic material (compost) increased fresh weight of spinach by 11% and dry weight by 5% whereas partially decomposed compost decreased the fresh weight by 33% and dry weight by 32% compared with control. Similarly, Loecke *et al*. (2004) found that composted manure increased corn grain yield more than fresh raw manure (10.3 vs. 8.8 Mg ha^{-1}). They also found that fresh manure decreased corn emergence by 9.5% compared with unamended/non-fertilized control treatment. Eremina *et al*. (2003) found a 13% less sugar beet root yield in response to incorporation of un-composted (raw) straw into soil compared to application of composted straw. Siddiqui (2004) also observed that un-composted farm yard manure with wider C: N ratio caused N deficiency in orchids.

The field study conducted to evaluate the effect of different application rates of N-enriched/mixed compost in the presence of supplementary dose of N fertilizer demonstrated that the 300 kg ha^{-1} compost enriched with 44 kg N was statistically similar in effectiveness when compared with 400 and 500 kg compost containing 44 kg N (Table 6). This implies that the integrated application of both organic waste material and mineral fertilizer in the field could be highly important and may release nutrients slowly and gradually, which consequently affect plant growth. Moreover, the application of 300 kg ha^{-1} enriched compost could be economical and more feasible for farmers.

Results of maize growth and yield indicated that the compost enriched with 44 kg N applied @ 300 kg ha^{-1} and supplemented with 88 kg N (50% of 175 kg N ha^{-1}) fertilizer was comparable to full dose of N fertilizer (urea). This implies saving of 25% N fertilizer without any reduction in maize yield. Thus compost enriched with N may reduce dependence on chemical fertilizers to some extent by enhancing their efficiency due to slow release (Chang and Janzen, 1996; Paul and Clark, 1996).

The novelty of our approach is that the enriched compost was applied at substantially low rates i.e. 300-500 kg ha^{-1}. Previously, researchers investigated the effect of compost/raw organic material by applying it in several t ha^{-1} (Cheuk *et al*., 2003; Nevens and Reheul, 2003; Wolkowski, 2003). The economic analysis indicate that this technology is cost effective because raw material is available free of cost and application of just 300 kg ha^{-1} is quite feasible for the farmers to be used as soil amendments and also will not create a demand-supply problem. The reduction in huge piling up of organic wastes is an extra benefit.

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