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Wheat Residue Management Improves Soil Fertility and Productivity of Maize

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Abstract

In cereal-based crop rotation, inappropriate residue management such as burning and removing may deteriorate soil properties and crop productivity. Proper crops residue management opens up the option for enhancing level of soil organic carbon which improves soil aggregates and other soil physical, chemical and biological properties. Due to scarcity of alternative organic amendments, retention of crop residues in the field can be considered key in promoting the soil health particularly in the agriculture system of developing countries. This study was conducted at research area, Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad to determine whether incorporation of wheat residues amended with desiccator and decomposed with bacterial strains improve crop growth and yield by affecting soil infiltration rate, soil tilth, nutrient and water holding. After harvesting, wheat crop residues were divided into two i.e., burning and incorporation of residues. Wheat residues were treated with desiccator (10, 15, 20 kg ha^{-1}) along with decomposing bacteria *Enterobacter* spp. MN-17 (2, 3, 4 L ha^{-1}) in different combinations and then incorporated into the soil after harvesting. Visual observation indicates that desiccator not only absorbed moisture from the residues but also softened and converted them into brittle and easily breakable form in 3-4 days. This facilitates quick composting of residues. Autumn maize was grown to test the response. Results revealed improved growth, yield, physiological parameters and nutrient use efficiency of maize in the treatment of incorporation of wheat crop residues compared to treatment of burning. More-over soil physical and chemical properties also improved due to the incorporation of wheat crop residue. Treatment receiving {(20 kg ha^{-1}) + (4 L inoculum of MN-17)} during wheat residue incorporation increased maize plant height (16.4%), number of leaves (11%), chlorophyll contents (9%) and grains yield (27%). Thus, it can be summarized that incorporation of crop residues improved growth and yield parameters of maize which could be the result of improved soil organic matter (SOC) and soil physical health. © 2018 Friends Science Publishers

Keywords: Crop residues; Burning; Incorporation; Drying agent; *Enterobacter* MN-17

Introduction

The term "residue", with meanings of something left over, gives a false idea to the value of residues and other vegetative parts of crops that remain after harvesting. Crop residues are a vital source of nutrients supply in systems where few inputs are used (Campbell *et al*., 1991; Nyborg *et al*., 1995; Soon, 1998). Residues represent a fraction of total organic carbon in the soil and promote accumulation near to the soil surface (Doran, 1980; Buchanan and King, 1992; Angers *et al*., 1997). Annual crop residues production is about 400 million ton per year in the world while over 10 million tones ha^{-1} in rice-wheat cropping system of Pakistan. Major nutrients (N, P & K) present in these residues are about 74 million tones per year. About 74% crop residue comes from cereal crops, 8% from legumes, 4% from oil crops, 9% from sugarcane and, 5% from tuber crops (Pathak *et al*., 2012). Use of inorganic fertilizers increased grains yield and labor effectiveness with corresponding decrease in the use of cover crops and organic fertilizer (Power and Papendick, 1985). However, residue management technique increases organic matter in soil, reduces soil and water erosion, saves nutrients from losses and groundwater from contamination (Reganold *et al*., 1987). A huge amount of fertilizers can also be saved by returning of residues produced in soil. Approximately 1.5 Pg (l Pg = 10^{-15} g) of carbon is present in residues, produced in the world, which is an important source of organic matter to the soils. These can also be used to improve the soil productivity and a major source of lignocellulose adding the soil (Smith and Sharpley, 1990). Awareness of environmental features of crop production and soil quality has been rising in recent years, which has led to transform the interest in crop residues.

For residues management, burning is an economical and easiest approach adopted by more 80% farmers. Due to lack of knowledge and not availability of suitable technologies, it is common practice everywhere in the world (Seline *et al*., 2015). Burning of residues degrades the

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atmospheric quality and a major source of carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), and volatile organic compounds (VOC), nitrogen oxides and halogen compounds and thus resulting in SMOG every year in India and Pakistan. Residue burning results in loss of precious organic matter source, evaporation of soil surface water, crust formation, accumulation of salt in root zone, killing of beneficial microbes and declining of soil organic carbon (Whitbread *et al*., 2000).

It was estimated that about 50% of the global CO_2 produced from the decomposition of annual litter (Coilteaux *et al*., 1995). No doubt, there is a huge pool of stable organic matter in the soil, but its decomposition is very slow (Smith and Sharpley, 1990; Campbell *et al*., 1991; Joergensen *et al*., 1995; Gaind *et al*., 2006). Managing the soil by incorporation of crop residues alters the soil environmental conditions for microorganisms which are essential for organic matter decomposition and nutrient cycling (Doran, 1980). The transformations of soil organic matter mostly depend on the soil decomposers activities (mainly soil microorganisms) which determine the recycling of nutrients essential to the dynamics of agro-ecosystems. Specificity of enzymes or substrate degradation is a major characteristic of soil microbes (Kshattriya *et al*., 1991) because the relative proportions of the different chemical compounds change due to different decomposition rates with time.

Crop residues incorporation moderately or completely in soil depends upon practices of cultivation (Dormaar and Carefoot, 1996). Various degrees of surface cover are achieved by residue incorporation, which controls soil erosion. In some parts of the United States, farmers adopt conservation tillage to keep minimum ground cover by stubbles about 30% (Griffith and Wollenhaupt, 1994). Maize (*Zea mays*) is 3rd important cereal crop in Pakistan as feed of livestock, preparation of silage, grain production and also used industrially for starch and oil extraction. Maize is an important source of protein, vitamin, carbohydrate, vitamin B and iron. Wheat (*Triticum aestivum* L.) is the major cereal crop of Pakistan. It is adapted well to the climatic and physiographic conditions of Punjab. Thus, residue management practices have been advocated to evaluate its effect on yield attributes, aggregation and C stabilization. Present study was undertaken to check the potential of drying agent and decomposing bacteria on wheat crop residues management and its effect on soil properties, carbon sequestration and maize yield sustainability.

Materials and Methods

Experimental Field Conditions

The experiment was conducted on maize in a crop rotation of wheat-maize at the research area, Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad, Pakistan. Trial was conducted at sandy loam textured soil with moderate drainage situated in a semi-arid region located 31º North latitude, 73ºEast longitude and 184 m above sea level. The soil physical and chemical properties are given in Table 1. Sub-samples of 10 g soil from each treatment were placed in a 120-mL flask, adjusted to 40% of WHC (water holding capacity) and air-tight sealed. A 10 mL headspace sample was taken from half of the flasks and which then injected with 10 mL acetylene (C_2H_2), i.e., 10 kPa or 10% v/v, to inhibit reduction of nitrous oxide (N_2O) to dinitrogen (N_2) (Balderstone *et al*., 1976). The flasks were incubated in dark at 25±1ºC. After 0, 1, 3, 7 days three flasks were selected at random and the headspace analyzed for N_2O. Soil organic matter was determined in the form of organic carbon based on Walkley-Black acid digestion method as described by Anderson and Domsch (1989). A conversion factor of 2 was used to calculate SOM (i.e., soil organic matter = 2 × soil organic carbon).

Inorganic C was determined by adding 5 mL 1 M hydrochloric acid (HCl) solution to 1 g air-dried soil and trapping CO_2 evolved in 20 mL 1 M NaOH. The CO_2 in the 1 M NaOH was determined by titration with 0.1 M HCl (Jenkinson and Powlson, 1976). Total N was measured by the Kjeldhal method using concentrated sulfuric acid (H_2SO_4) and hydrogen peroxide (H_2O_2) to digest the sample (Bremner, 1996). ECe was determined by conductivity meter (JENWAY, soil pH was determined by pH meter (JENWAY), available phosphorus was determined by Olsen method (T80 UV/VIS Spectrometer) and potassium was determined by Flame photometer (410 Sherwood).

Treatments Description

Wheat was sown by drill-seeded and fertilized through broadcast method at recommended rate. Full dose of phosphorus (DAP) and potassium (SOP) were applied at sowing time and nitrogen (Urea) in two splits. After wheat harvesting, the above ground wheat residues were divided into two fractions (burning and incorporation of residues). Eight treatments consisted of control (T_1), burning of wheat residues (T_2), desiccator @ 10 kg ha^{-1} (T_3), desiccator @ 15 kg ha^{-1} (T_4), desiccator @ 20 kg ha^{-1} (T_5), T_3 + inoculum 2 L ha^{-1} (T_6), T_4 + inoculum 3 L ha^{-1} (T_7), T_5 + inoculum 4 L ha^{-1} (T_8). Treatments were replicated three times and laid down in randomized complete block design.

Crop Husbandry

Plotting was done in a field vacated for maize crop where the stubbles of wheat were left behind at harvesting. The weight of wheat stubbles was recorded from unit area (m^{-2}). The same amount was assumed to be present present in the all plots as well. The chemical composition of wheat residues is given in Table 2. In the burnt treated plots, sun-dried stubbles were burnt. In case of soil incorporation; the residues were incorporated with the help of disk plough. For easy and proper mixing of wheat residue into the soil drying agent was sprayed on wheat residues. Three levels of drying agent (mixture of salt of warm wood: dipotassium salt: sodium sulfate in 1:1:1 ratio) 10, 15 and 20 kg ha^{-1}, respectively were used. Drying agent was sprayed on wheat residues separately as well as along with inoculum (2, 3, 4 L ha^{-1}).

Inoculum Preparation

Pre-isolated endophytic bacterial strains *Enterobacter* spp. MN-17 was used in this experiment. Inocula of the preferred strains were prepared in 10% tryptic soy broth (TSB) in 250 mL Erlenmeyer flasks. The flasks were inoculated with bacterial loop full and incubated for 72 h at 28 ± 1°C in an orbital shaking incubator (Firstek Scientific, Tokyo, Japan) at 100 rpm. The optical density of the broth was adjusted from 0.5 CFU/mL measured at 600 nm using spectrophotometer to achieve a consistent population of bacterial strains in the broth before application. Inoculum was sprayed for the purpose to enhance the decomposition rate. Desiccator was simply dissolved in tape water and sprayed on residues, then incorporated into the soil after two days of spay.

Similar treatment plan was used for maize sowing like wheat residue incorporation. After 45 days of burial the wheat residues in soil maize variety, DK6714 Hybrid (seed rate @ 10 kg $acre^{-1}$) was planted to check the effect of drying agent and decomposing bacterial strain on growth and yield of maize. Recommended doses of NPK were applied at the rate of 175, 120, 90 kg ha^{-1}, respectively. The N, P and K sources were urea, diammonium phosphate (DAP) and murate of potash (MOP), respectively. All phosphorus and potassium containing fertilizers were applied during seed bed preparation. Nitrogen was applied in three splits. The basal dose was applied before sowing and remaining 2 doses were applied with 2ndand 3rd irrigations. All the cultural and irrigation practices were kept same for all the treatments. At harvest, grain and straw yield were computed for each plot. The total productivity of crop was worked out while biological yield was calculated by the formula as given:

Biological yield = Total biomass of plants in the plot (grains + straw yield)

Soil and Plant Sampling

Composite samples of soil were collected from 0 to 15 cm depth after removing the litter from surface soil at randomly selected plots, before the maize crop was sown in and after the crop harvest, and were analyzed (Table 1). A soil auger was used to sample the soil for examination of the soil's physical and chemical properties. Soil samples were air dried, ground to pass a 2 mm sieve, and analyzed for total soil nitrogen, phosphorus, potassium, soil pH, EC and total organic matter determination.

The maize crop was harvested at the time of maturity. Data regarding growth parameters like plant height, leaf length, number of leaves, cob length and cob girth were collected before harvesting. The height was recorded with the help of a measuring tape from the point where root begins to the upper tips of the leaves of the plant and then average was taken. Plant leaf area (3rd leaf from top) was recorded using LI-3100C Area Meter (Li-Cor, Inc., Lin-coln, NE, USA). The chlorophyll contents were measured by using Chlorophyll Meter (SPAD 502 Plus, Minolta, Japan). All data was measured from ten samples and average was used. After harvesting 8-10 plants were randomly selected from each plot to collect the data and their average was recorded i.e., grain yield, and biological yield. For the purpose of grain yield number of plants was collected in total area, and grain yield was recorded in kg ha^{-1}. N, P and Kanalysis were done in soil fertility and plant nutrition lab, Institute of Soil and Environmental Sciences.

Statistical Analysis

To assess the significance ($P \leq 0.05$) of treatment effects, honest significant differences (HSD) were performed to achieve the detailed information about the differences among the treatments average by performing the analysis of variance (ANOVA) according to the procedure given by Steel and Torrie (1997).

Results

Effect of Wheat Residue Incorporation on Maize Agronomic Parameters

Incorporation of wheat crop residues amended with desiccator and decomposing bacteria showed more outcomes than traditional approach (burning) because improvement in plant height was higher in treatment receiving 20 kg ha^{-1} desiccator along with 4 L ha^{-1} inoculum. It was obvious from results that maximum increment in plant height was16.4% in field experiment for treatment where wheat residues were incorporated into the soil amended woth 20 kg ha^{-1} desiccator and 4 L ha^{-1} decomposing bacteria (Table 3). Chlorophyll contents were increased in response to wheat residue incorporation. Results revealed that residue incorporation with different concentrations of drying agent and decomposing bacterial strains improved chlorophyll contents as compared to traditional approach (burning). Incorporation of wheat residues along with 20 kg ha^{-1} desiccator and 4 L ha^{-1} bacteria improved 9% chlorophyll contents under field conditions as compared to burning(Table 3). Effect of different rates of desiccator in wheat residue incorporated treatments on leaf length and number of leaves were through differential until it was conspicuous in all residue incorporated treatments compared to burning treatment. Results showed that there was upto 10 to 12% increase in leaf length and number of leaves, respectively in treatment where wheat residues were incorporated in the field along with 20 kg ha^{-1} desiccator and 4 L ha^{-1}decomposing bacterial strains (Table 3) as compared to the burning treatments. Additionally, a considerable enhancement in cob length was observed with the incorporation of wheat crop residue

Table 1: Physico-chemical properties of soil before and after wheat residues incorporation

Soil Parameter	Unit	Before residue incorporation	After residue incorporation
Sand	%	52.06	-
Silt	%	22.54	-
Clay	%	25.74	-
Textural class	-	Sandy loam	-
Saturation percentage	%	32.45	34.05
PHs	-	7.67	7.23
Electrical conductivity	(dS m^{-1})	1.47	1.32
Organic C	(g kg^{-1} soil)	2.60	6.67
Total Kjeldahl N	(g kg^{-1} soil)	0.34	0.88
Available P	(mg kg^{-1} soil)	7.42	10.97
Available K	(mg kg^{-1} soil)	121	139
Organic matter	(%)	4.32	6.75

Table 2: Chemical composition of wheat residues

Component	Percentage (%)
Dry matter	88-95
Metabolized energy mcal/lb	0.68
Crude Protein	3.6
Acid detergent fiber	54
Cellulose	33.7-41
Hemicellulose	21-27
Lignin	12-22.8
Ash	7-9.8
Phosphorus	0.05
Calcium	0.19

(Yasin *et al.*, 2010)

Table 3: Effect of wheat residue incorporation on agronomic and physiological parameters of maize

Treatments	Plant height (cm)	Number of leaves $plant^{-1}$	Cob length (cm)	Cob girth (cm)	Number of grains per Cob	Stalk fresh weight kg m^{-2}	Chl. Content (SPAD)	1000 grain weight	Grain yield	Biological yield
								Weight (g)		
								(g)	kg ha^{-1}	
Control	198d	10a	12d	10.066b	398b	4.56f	37.67b	220.33e	1666b	7298d
Burning of residues	208cd	11ab	12.4cd	11.76ab	442ab	4.92ef	45.706ab	238.33de	2208ab	11333c
Dessiccator @ 10 kg ha^{-1}	218b-d	11.46ab	12.86b-d	12.54ab	458ab	5.46de	48.97ab	247.12c-e	2316ab	13000bc
Desiccator @ 15 kg ha^{-1}	228b-d	12.38ab	13.56a-d	13.56ab	472ab	5.73cd	52.71ab	258.66cd	2398a	14230a-c
Desiccator @ 20 kg ha^{-1}	236a-d	12.96ab	14.89a-d	13.78ab	492ab	6.58bc	54.9a	268.34 b-d	2495a	15429ab
Dessiccator @ 10 kg ha^{-1}- + inocula 2 L ha^{-1}	246a-c	13ab	15.22a-c	14.62ab	508a	7.03ab	55.74a	280.94bc	2542a	16514a
Desiccator @ 15 kg ha^{-1}+ inocula 3 L ha^{-1}	252ab	13.28ab	15.78ab	14.86ab	524a	7.33ab	56.03a	301.65ab	2648a	16957a
Desiccator @ 20 kg ha^{-1}+ inocula 4 L ha^{-1}	268a	13.72a	16.12a	15.35a	546a	7.63a	57.9a	318.98a	2756a	17124a
HSD	41.578	2972	3.1554	4.1959	119.22	0.8293	15.468	38.197	652.66	3375.9

Note: All treatments except control contain recommended doses of N, P and K fertilizers as urea, DAP and MOP respectively, (inocula= MN-17 Bacterial strain). Values followed by the same letter were not significantly different at the 5% level of significance

receiving 20 kg ha^{-1} desiccator a long with 4 L ha^{-1} inoculum. There was 27% increment recorded over respective burned treatment (Table 3). Incorporation of residues ehnanced cob girth appreciably 18% in field with respect to the burning plots (Table 3). Correspondingly, there was 28% increment in 1000 grain weight of plotreceiving 20 kg ha^{-1} desiccator along with decomposing bacteria than burning treatment (Table 3). Incorporation of wheat crop residues depressed grain yield of maize by 31.7% at the rate of 20 kg ha^{-1} desiccator inoculated with 4 L ha^{-1} inoculum. However, biological yield of maize was also considerably improved in response to wheat residue incorporation. The burning of wheat residues gave inferior results in biological yield while incorporation of wheat residues depressed the biological yield of maize crop. Wheat residues treated with 20 kg ha^{-1} desiccator along with decomposing bacteria caused 34% upsurge in biological yield of maize crop on an average under field condition as compared to burning as shown in Fig. 2. Furthermore, promising results were recorded in terms of stalk fresh and dry weight of maize crop.Enhancement in stalk fresh and dry weight has been recorded in residue incorporated treatment plots by the application of drying agent and decomposing bacteria. There was significant increase in stalk fresh and dry weights in wheat residue incorporated treatments. There was 22 and 18% increment in stalk fresh weight and dry weights, respectively by the incorporation of wheat residues sprayed with 20 kg ha^{-1} desiccator and 4 L ha^{-1} inoculum (Table 3). Residue incorporation considerably increased the nutrient uptake efficiency. The N concentration in maize straw was significantly affected by the incorporation of wheat residues into the plots (Table 4). Incorporation of wheat residues increase the nutrient uptake efficiency of succeding crop due to decomposition of wheat residues. There was 21% increase in stalk N in residue incorporated treatments as compared to burning. Wheat residue incorporation also significantly affectd the P concentration in maize stalk. There was about 16% more P uptake in residue incorporated treatments rather than burning (Table 4). More P availability in wheat residue incorporated plots was might be due to more mineralization. K concentration was also significantly affected by the incorporation of wheat residues (Table 4). The greatest K concentration was observed in 20 kg desiccator along with 4 liter inoccula where wheat residues were incorporated into the soil amended with drying agent and decomposing bacterial strains. Maximum increase in grain N concentration was observed in 20 kg desiccator ammended with 4 liter inoccula where wheat residues were incorporated into the field. There was 16% raise of N concentration in maize grains than burning. Results revaled that wheat residue incorporation treated with 20 kg per ha desiccator and decomposing bacteria appreciably increased the N concentration in grains. The effect of wheat residue incorporation on Pcontents in grain was evident and 26% increase in P concentration in maize grain in wheat residue incorporated treatments as compared to the burning. The efficiency of K was increased in wheat residue incorporated treatments than burning. Maximum increase in K concentration in maize grain was recorded in 20 kg desiccator along with 4 liter inoccula. There was 21% increase in K concentration in grains, higher than burning (Table 4).

Effect of Wheat Residues Incorporation on Soil Physico-chemical Properties

Nutrient release pattern in soil was significantly affected by wheat residue incorporation. The results showed that the incorporation of wheat residue in soil increased N, P and K concentration which improved the soil fertility status, soil properties. The results for soil total N are statistically more pronounced as compared with the burning treatment (Table 1). Incorporation of wheat residues showed significant results over burned treatments on concentration of P. The percent increase in organic carbon was 21% (Table 4). However, residue incorporation with application of drying agent and decomposing bacterial strains significantly increased soil organic C against the burning practices. The least soil organic C was noted for the stubble removal treatments with values statistically comparable with the treatment of burning without N (Table 4). In this study analysis of variance showed that across all treatments except control and

Table 4: Effect of wheat residue incorporation on N, P and K concentrations in maize grains, stalk after harvest and soil properties

Treatments	N in grain	P in grain	K in grain	N in stalk	P in stalk	K in stalk	Soil organic C (%)
	(%)						
Control	1.1e	0.078a	1.46d	0.92d	0.17d	1.72c	8.47d
Burning of residues	1.41d	0.13ab	1.51cd	1.13cd	0.3cd	1.93bc	9.74d
Dessiccator @ 10 kg ha^{-1}	1.5cd	0.19ab	1.57cd	1.27bcd	0.33bc	2.31abc	10.47cd
Desiccator @ 15 kg ha^{-1}	1.55bcd	0.2ab	1.63cd	1.43abc	0.36abc	2.24abc	11.21bcd
Desiccator @ 20 kg ha^{-1}	1.62abcd	0.23ab	1.80bcd	1.47abc	0.39abc	2.44ab	12.76abc
Dessiccator @ 10 kg ha^{-1}+ inocula 2 L ha^{-1}	1.7abc	0.28ab	2.12abc	1.52ab	0.42abc	2.46ab	13.22abc
Desiccator @ 15 kg ha^{-1}+ inocula 3 L ha^{-1}	1.79ab	0.31ab	2.32ab	1.71a	0.45ab	2.55ab	13.59ab
Desiccator @ 20 kg ha^{-1}+ inocula 4 L ha^{-1}	1.87a	0.34b	2.52a	1.79a	0.49a	2.68a	14.44a
HSD	0.2592	0.5283	0.5982	0.3891	0.1388	0.6215	2.78

Note: All treatments except control contain recommended doses of N, P and K fertilizers as urea, DAP and MOP respectively, (inocula= MN-17 Bacterial strain). Values followed by the same letter were not significantly different at the 5% level of significance

Table 5: Effect of wheat residue incorporation on emission of N_2O, N_2 and C_2O

Treatments	Emission of N_2O (ng N $kg^{-1}day^{-1}$)	Emission of N_2 (ng N $kg^{-1}day^{-1}$)	Production of CO_2-C (mg kg^{-1} day^{-1})
Control	186d	546c	19e
Burning of residues	172cd	362c	17de
Dessiccator @ 10 kg ha^{-1}	160 b-d	145c	14.33de
Desiccator @ 15 kg ha^{-1}	148 b-d	126c	12.66 c-e
Desiccator @ 20 kg ha^{-1}	135 a-c	110c	11cd
Dessiccator @ 10 kg ha^{-1}+ inocula 2 L ha^{-1}	130ab	104c	9.33bc
Desiccator @ 15 kg ha^{-1}+ inocula 3 L ha^{-1}	110ab	88b	8.67ab
Desiccator @ 20 kg ha^{-1}+ inocula 4 L ha^{-1}	90a	68a	8a
HSD	46.330	154.96	4.245
Treatments	Emission of N_2O (ng N $kg^{-1}day^{-1}$)	Emission of N_2 (ng N $kg^{-1}day^{-1}$)	Production of CO_2-C (mg kg^{-1} day^{-1})

Note: All treatments except control contain recommended doses of N, P and K fertilizers as urea, DAP and MOP respectively (inocula= MN-17 Bacterial strain). Values followed by the same letter were not significantly different at the 5% level of significance burning, soil pH in the top 15 cm changed from 7.6-7.3. The decrease in soil pH is due to wheat residue incorporation. Soil pH decreased 6% (Table 1), higher pH was recorded in residue burned plots. Soil EC decreased 8% treatment in which wheat crop residues were incorporated into the soil by treating 20 kg desiccator along with 4 L inoccula (Table 1). Results showed that there was greater organic matter in plots where wheat crop residues were incorporated into the soil as compared to the burning treatments (Table 1). And 15% increment in soil organic matter in 20 kg desiccator along with 4 L inoccula was found where wheat residues incorporated into the soil amended with drying agent and decomposing bacterial strains than burned treatment.

Emission of Gasses

The emission of gasses was highly variable in residue incorporated and burned plots. Emission of N_2 was > 11 ng N kg^{-1} day^{-1} in residue burned plots as compared to residue incorporated plots (Table 5). Burning decreased the N mineralization rate 1.4 times as compared to residue incorporation. This decrease in N mineralization, was reflected to decreaseinnon in organic carbon. N_2O emission rate was also higly variable in burned and incorporated plots. The amount of N_2O emitted during wheat residue burning ranged from 90-250 ng N kg^{-1} d^{-1}. Our results showed that average NO_2 was higher when residues burned as compared to the incorporation. This suggest that oxidation of NO_2 might be inhibited by burning of wheat residues. Burning of residues also increased the CO_2 emission than incorporation of residues. There was 52% evaluation of CO_2 in residue incorporated plots amended with drying agent and decomposing bacterial strains versus residue burned plots.

Discussion

This study was conducted to check the effect of drying agent and decomposing bacteria on wheat crop residues management and its effect on growth, yield and nutrient uptake efficiency of maize crop. Incorporation of crop residues is an alternative approach for managing the residues after harvest and to reduce the emission of gasses. Drying agent with decomposing bacterial strains increase growth parameters including plant height, plant weight and yield parameters such as total number of grains, biological yield significantly compared to control.

Analysis of variance showed that wheat residue incorporation improved the yield and growth of maize crop as compared to the burning treatment. Several reasons involved in improving the yield of succedingcrop after the incorporation of wheat crop residues such as improving soil properties conducive for maize growth. Maximium plant height was recorded in residue incorporated plot treated with 20 kg ha^{-1} drying agent and 4 L inoculum as compared to the burning. There was 21% increment in plant height by the incorporation of wheat crop residues (Fig. 1). The plant

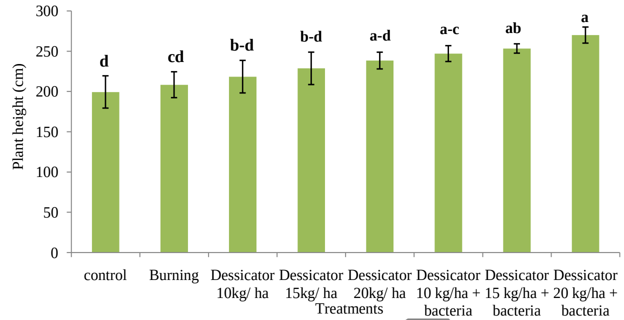

Fig. 1: Increase in plant height by wheat residue incorporation amended with drying agent and decomposing bacteria

Note: All treatments except control contain recommended doses of N, P and K fertilizers as urea, DAP and MOP respectively (Bacteria=MN-17). Values followed by the same letter were not significantly different at the 5% level of significance

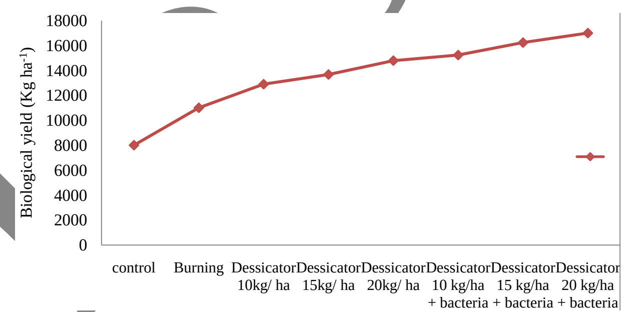

Fig. 2: Increase in biological yield by wheat residue incorporation amended with drying agent and decomposing bacteria

Note: All treatments except control contain recommended doses of N, P and K fertilizers as urea, DAP and MOP, respectively (Bacteria=MN-17)

height was promoted in wheat residue incorporated plots because of improving the soil physico-chemical properties. Residue incorporation resulted in release and turnover of nutrients which might cause changes in soil parameters like moisture contents,nutrient cycling and holding and improvement in soil prosity which are necessary for balance supply of water and nutrients to growing crop. Thus resulted in good crop growth (Haunge *et al.*, 2013). Reduction in plant height was most pronounced in the treatment where residues was burnt. This reduction in plant height was probably due to loss of nutrients and ambient organic matter in soil. Grain yield of maize was also produced more in treated residues incorporation treatment compared to burning. These results are depicted from significantly increased 1000-grains weight in whreat residue incorporated plots (Table 3) compared to the burning treatment. Burning might affect photosynthesisdue to loss of carbon in the soil and thus resulted in the less grain production (Haunge *et al.*, 2013).

Higher maize grain yield was recorded in case of residue incorporation along with drying agent (dessicator) and decomposing bacteria compared with residue burning treatment. In this study residue incorporation significamtly increased the grain and biological yield. This might be due to improvement in the soil organic carbon, less nutrient leaching, more recycling of nutrients, minimize evaporation, lowering soil heat due to more water holding and least soil crust formation at surface.The yield despaired due to burning at cropmaturity showed27%reduction in biological yield (Table. 3). Moreover, higher maize grain yield was recorded in 20 kg desiccator embaded with 4 L bacteria compared to burning. Incorporation of wheat crop residues close to soil surface improvedorganic carbon, give up nutrients, minimize evapotranspiration and conserve more soil moisture (Sadeghi, 2007).

Incorporation of crop residues indicated a potential for improvement of nutrient uptake efficiency of maize crop due to the process of mineralizationto improve soil fertility status, therefore, it is recommended that stubble incorporation shouldbe practiced to increase crops productivity by improving the soilnutrient storage capacity. This approach leads to less use of inorganic fertilizers (Haunge *et al*., 2013) and water. The foregoing results indicated that there was more N, P and K contents in maize stalk and grains as compared toplants in residues burning plots (Table 4). Burning of wheat crop residues caused decrease in N, P and K contents in maize stalk (31, 17 and 11%, respectively). Analysis showed that maize crop was healthier due to 11 to 17% more N and 8 to 12% more P contents in maize stalk.

Availability of substrate combined with enhanced microbial activity increased soil mineral N in soil through decomposition of organic matter, soil mineral N can be increased. Soil inorganic N level was less in residues burned treatment at the depth of 0-15 cm (Table 1), which is 27% lower than the normal soil N contents. A significant increase in soil N pool was noted in residues incorporated plots due to decomposition of wheat crop residues. Mineral N was increased in all wheat residue incorporated treatments due to the process ofdecomposition and mineralization. Results revaled 13.2 to 18.2% improvement in the inorganic soil N pool in the residue incorporation treatment. It appears an excellent outlook for reducing the existing farmer fertilizer N inputs. High soil N rate is probable to alleviate the effect of microbial N immobilization due to theavailability of N (Thuy *et al*., 2008). Residue incorporation supposedly resulted in less fixation of soil inorganic P and K, consequently resulted in a relatively high ambient soil inorganic P and K contents in residue incorporation plots (Table 1). Results showed that residue incorporation increased the soil P and K contents in soil irrespective of its depth. Increased availability of P and K with residue incorporated treatments couldbe due to the addition of nutrients through residue and its release through production of organic acids (Schmidt-Rohr *et al*., 2004). The increase in soil total P and K was due to the carry over effect of the P and K previously applied in inorganic form or from crop residue or both.

Incorporation of wheat crop residue probably increased the soil organic matter by improving the soil infiltration and increased soil moisture conservation (Sadeghi, 2007). Residue incorporation improved water holding capacity by lowering the evaporation losses. Wheat residue incorporation showed significant increase in organic matter content. Soil organic matter depend upon decomposition process and wheat residue mostly provide an environment suitable for decomposition. Organic matter produced in higher amount in plots where crop residues were incorporated in the soil treated with drying agent and decomposing bacterial strains due to higher decomposition rate.

Soil organic carbonincreased by the incorporation of wheat crop residues. Organic carbon (OC) concentration of the surface (0–15 cm depth) soil summarized in Table 4. The complete removal of wheat crop stubbles by burning, the soil carbon contents were very low (Sadeghi, 2007). Wheat crop residue incorporation returned to soil, accompanied by better N concentration resulted in soil organic carbon levels enhanced which contribute to improve the soil productivity, quality and increased efficiency of carbon sequestration into the soil. In this study incorporation of wheat residues close to the soil surface improved organic C and relinquish nutrients. Increment in concentration of soil organic carbon subsequent residue incorporation was observed compared with the soils in which residues were burned. The constant C/Nratios suggest dynamics similar for organic carbon and total nitrogen. Residue burning with high C:N ratio condense N immobilization. Heating might also break up soil aggregates, thereby healing previously physically stabilized organic material (Blevins and Lukaszewski, 1998). The N_2O emission rate was highly variable among residue incorporated and burning treatments (Table 5). The N_2 release was also highly erratic and ranged from near imperceptible amounts to >1000 ng N kg $^{-1}$ soil day^{-1}. The amount of N_2 producein residue burned treatments was >10 times higher than the residue incorporated treatments (Table 5). Emission of CO_2 may be reduced due to stop biomass burning. It not only reducing the atmospheric pollution and climate problem but also helpful to fulfil the energy demand with improve the economic condition of the country (Jacobson, 2004).

Conclusion

In conclusion, our results suggest that wheat residue incorporation amended with drying agent and decompoing bacteria has positive effects on maize grain yield, facilitate nutrient uptake efficiency. The incorporation of wheat residue before sowing of maize crop is most effective in improving organic C, available P and K. Thus, wheat residue incorporation leads to improve the soil fertility status and increase the maize yield by suppling more nutrients due to mineralization. The results from emission of gasses for wheat residue burning treatments imply that wheat residue incorpotaion can cobe with incorporated organic residues.

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References

Angers, D.A., M.A. Bolinder, M.R. Carter, E.G. Gregorich, C.E. Drury, B. Liang, R.P. Voroney, R.R. Simard, R.G. Donald, R.P. Beyaert and J. Martel, 1997. Impact of tillage practices on organic carbon and nitrogen storage in cool, humid soils of eastern Canada. *Soil Till. Res.,* 41: 191-201

Anderson, T.H. and K.H. Domsch, 1989. Ratios of microbial biomass carbon to total organic carbon in arable soils. *Soil Biol. Biochem.,* 21: 471-479

Balderstone, W.L., B. Sherr and W.J. Payne, 1976. Blockage by acetylene of nitrous oxide reduction in *Pseudomonas perfectomarinus. Appl. Environ. Microbiol.*, 504-508

Bremner, J.M., 1996. Nitrogen-Total. *In: Methods of Soil Analysis: Part 3-Chemical Methods*, pp: 1085-1122. Spark, D.L. (ed.). Soil Science Society of America Inc., American Society of Agronomy, Inc., Madison, Wisconsin, USA

Buchanan, M. and L.D. King, 1992. Seasonal fluctuations in soil microbial biomass carbon, phosphorous and activity in no-till and reduced-chemical-input maize agroecosystems. *Biol. Fertil. Soils,* 13: 211-217

Blevins, D.G. and K.M. Lukaszewski, 1998. Boron in plant structure and function. *Ann. Rev. Plant. Physiol. Plant Mol. Biol*., 49: 481-500

Campbell, C.D., C.M. Cameron, B.A. Bastias, C. Chen and J.W.G. Cairney, 1991. Long term repeated burning in a wet sclerophyll forest reduces fungal and bacterial biomass and responses to carbon substrates. *Soil Biol. Biochem*., 40: 2246-2252

Coilteaux, R., A. Breiman and D. Graur, 1995. Wheat Evaluation. *Israel J. Plant Sci*., 43: 58-95

Dormaar, J.F. and E.D. Carefoot, 1996. Burning crop residues: Effect on selected soil characteristics and long-term wheat yields. *Can. J. Soil Sci.,* 59: 79-86

Doran, J.W., 1980. Soil microbial and biochemical changes associated with reduced tillage. *Soil Sci. Soc. Amer. J.,* 44: 765-771

Griffith, D.R. and N.C. Wollenhaupt, 1994. Crop residue management strategies for the Midwest. *In*: "*Crops Residue Management*", pp: IS-36. Hatfield, L. and B.A. Stewart (eds.). Lewis Publishers, New York

Gaind, S., A.K. Pandey and Lata, 2006. Microbial biomass, P-Nutrition, and enzymatic activities of wheat soil in response phosphorus enriched organic and inorganic manures. *J. Environ. Sci. Health.,* 41: 177-187

Haunge, Q., S. Laixiang, X. Xinliang, C. Yaqing and B. Junfei, 2013. Effect of residue retention on paddy crop. *Soil Biol. Biochem*., 64: 110-123

Jenkinson, D.S. and D.S. Powlson, 1976. The effects of biocidal treatments on metabolism in soil Fumigation with chloroform. *Soil Biol. Biochem.,* 8: 167-177

Joergensen, R.G., H. Kubler, B. Meyer and V. Wolters, 1995. Microbial biomas phosphorus in soils of beech (*Fagussylvatica* L.) forests. *Biol. Fertil. Soil.,* 19: 215-219

Jacobson, M.Z., 2004. The short-term cooling but long-term global warming due to biomass burning. *J. Climate,* 17: 2909-2926

Kshattriya, S., G.D. Sharma and R.R. Mishra, 1991. Enzyme activities related to litter decomposition in forests of different age and altitude in north east India. *Soil Biol. Biochem.,* 24: 265-270

Nyborg, M., E.D. Solberg, S.S. Malhi and R.C. Isauralde, 1995. *In*: *Fertiliser N, Crop Residue, and Tillage Alter Soil C and N Content in a Decade*, pp: 93-101. Lal, R., J. Kimble, E. Levine and B.A. Stewart (eds.)

Power, J.E. and R.I. Papendick, 1985. Organic sources of nutrients. In "Fertilizer Technology and Use". *Soil Sci. Soc.,* 3: 503-520

Pathak, H., C. Devakumar, P.K. Chhonkar, R.K. Gupta, P.S. Pathak and A.K. Sikka, 2012. *Management of Crop Residues in the Context of Conservation Agriculture*, pp: 0-12. Policy Paper No. 58, National Academy Agric. Sci. New Delhi, India

Reganold, J.P., L.E. Elliott and Y.L. Unger, 1987. Long-term effects of organic and conventional Farming on soil erosion. *Nature*, 330: 370-372

Schmidt-Rohr, K., J.D. Mao and D.C. Olk, 2004. Nitrogen-bonded aromatics in soil organic matter and their implications for a yield decline in intensive rice cropping. *Proc. Natl. Acad. Sci*, 101: 6351-6354

Sadeghi, H., 2007. Effects of crop residue and nitrogen rates on morpho-physiological traits, yield and yield components of two dryland wheat cultivars. *Ph.D. Thesis*, Shiraz University, Shiraz, Iran. (In Farsi with English abstract)

Seline, S.M., D. Catacutan, C.A. Oluyede, W. Gudeta and M. Nieuwenhuis, 2015. The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *Int. J. Agric. Sustain.*, 13: 40-54

Soon, Y.K., 1998. Crop residue and fertilizer management effects on some biological and chemical properties of a Dark Grey Solod. *Can. J. Soil Sci.,* 78: 707-713

Smith, S.J. and A.N. Sharpley. 1990. Soil nitrogen mineralisation in the presence of surface and incorporated crop residues. *Agron. J*., 82: 112-116

Steel, R. and G.D. Torrie, 1997. *Principles and Procedures of Statistics: a Biometrical Approach*. New York: McGROW-HILL. 633ped. Mc. Grawhill, Book corp. Inc., Ny, USA

Thuy, N.H., Y. Shan, B. Singh, K. Wang, Z. Cai and Y. Singh, 2008. Nitrogen supply in rice-based cropping systems as affected by crop residue management. *Soil Sci. Soc. Amer. J.,* 72: 514-523

Whitbread, A., G. Blair and R. Lefroy, 2000. Managing legume leys residues and fertilizers to enhance the sustainability of wheat cropping systems in Australia. The effects on wheat yields and nutrient balances. *Soil Till. Res.,* 54: 63-75

Yasin, M., A.W. Bhutto, A.A. Bazmi and S. Karim, 2010. Efficient utilization of rice-wheat straw to produce value added composite products. *Int. J. Chem. Environ. Eng.,* 1: 136-143

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