Response of Wheat to Farmyard Manure and Zinc Application in a Vertisol of Central India

ABSTRACT

Zinc (Zn) deficiency is one of the major global nutrition concerns, particularly in regions where diets are cereal dominant. About 50% of soils poor in zinc have resulted in zinc deficiency in cereal grains. Farmyard manure (FYM) with Zn application is the way to meet the Zn needs of crops and to raise the Zn content of grain that is ultimately consumed by people. Therefore, a pot experiment was conducted at the Department of Soil Science and Agricultural Chemistry of JNKVV, Jabalpur, in the Rabi season of 2020-2021 with three levels of FYM (0, 5.0, and 10 t ha-1) and three levels of zinc (0, 5 and 10 kg Zn ha-1) through ZnSO4.7H2O in a completely randomized design (CRD). Results revealed that the addition of 5 t FYM ha-1 + 10 kg Zn ha-1 produced significantly better results for the plant height compared to the control. The combined application of 10 t FYM ha-1 + 10 kg Zn ha-1 showed the highest SPAD reading at 21 DAS, but it was the highest at the sole application of 10 t FYM ha-1 at 45 DAS. Significant enhancements in spike length (7.65 cm), weight and number of grains per spike (23.90), and DMP of 7.12 g pot-1 were recorded with the 5 kg Zn ha-1 sole application. However, the highest grain weight (2.50 g pot-1) was recorded with 5 t FYM ha-1 + 5 kg Zn ha-1, which was on par with 5 t FYM ha-1, 5 kg Zn ha-1, and 10 t FYM ha-1+10 kg Zn ha-1. The highest Zn content (48.95 mg kg-1) in wheat grain was recorded with 10 kg Zn ha-1, followed by 5 t FYM ha-1 + 10 kg Zn ha-1 (44.45 mg kg-1). The highest Zn uptake of 99.53 µg pot-1 by grain of wheat was recorded with 5 t FYM ha-1 + 5 kg Zn ha-1, which was significantly superior to all the treatments but on par with 5 kg Zn ha-1 (98.82 µg pot-1). Combined application of 5 t FYM ha-1 +10 kg Zn ha-1 maintain extractable zinc in soil as compared to control.

Keywords: Farm yard manure (FYM), SPAD, Zinc, Wheat, Vertisol

1. INTRODUCTION

Wheat (Triticumaestivum) is an important Rabi crop grown in Madhya Pradesh, India. It is a significant ingredient in the daily diet of millions of people. The approximate chemical composition of the wheat kernel is starch 63–71%; protein 10-12%; water 8–17%; cellulose 2-3%; fat 1.5–2%; sugar 2-3%; and mineral matter 1.5–2% [1]. It plays an imperative role in the human diet and also provides strong monetary support for the country [2].

In high-input agriculture, deficiency of micronutrients has become a major constraint on the productivity, stability, and sustainability of soils. These deficiencies appeared much faster, primarily due to the fast adoption of new agricultural technology, including the cultivation of high-yielding crop varieties, an increase in cropping intensity, the expansion of irrigation facilities, the more frequent use of high-analysis fertilizers, and poor-quality irrigation water. The imbalanced fertilizer application, coupled with zinc deficiency, is one of the factors responsible for the low productivity of crops. Zinc deficiency in coarse-textured, calcareous, alkaline soils with a high pH and low organic matter is generally low in available zinc. Therefore, zinc malnutrition has become a major health concern among resource-poor people.

Among micronutrients, Zn is now being regarded as the third most limiting nutrient element in crop production after N and P. Cereal crops are inherently very low in grain Zn concentrations and growing them on potentially Zn-deficient soils further reduces Zn concentrations in grain [3]. To obtain high yields without deterioration of soil fertility, it is important to work out the optimal combination of fertilizers and manures in the cropping system [4].

In India, increasing the productivity of wheat has become a major way to overcome the unusual increase in population. In the literature, several workers showed the importance of farmyard manure in increasing cereal grain yield. The various physico-chemical processes also mediated the Zn availability in alkaline soils [5] i.e., variation in chemical composition of salt-affected soils, precipitation-dissolution reactions, adsorption kinetics, transformations of nutrients, and crop responses to applied nutrients greatly varied [6, 7]. Application of micronutrients determines the yield potential of crops in deficient soil with low carbon content [8, 9]. The use of FYM and other organic manures produces various types of organic acids during microbial decomposition and converts the plant nutrients from immobile to mobile in the soil solution [10]. Combined soil application of micronutrients with FYM significantly enhanced the mustard yield in normal soil [11].

Organic manures not only supply micronutrients but also influence the transformation of native micronutrients in soil, thereby enhancing their availability for crops [12, 13]. The contributions of soil organic matter to available pools of micronutrients are limited and, thus, prone to deficiency of one or more micronutrients in salt-affected soils [14]. Manures contribute to Zn accumulation through N supply and organic acids, decreasing soil pH and improving the mobilization of soil Zn in calcareous soils. Decomposition of organic materials releases fluvic and other organic acids [15] that form complexes with inorganic Zn and increase its solubility and availability to plants [16].

A significant decrease of 80% in grain Zn concentration was observed in cereals grown on soils with low plant-available Zn. This decrease in grain Zn also reduces its bioavailability in humans and may contribute to Zn deficiency in susceptible human populations. The poor recovery of zinc by crops necessitates the adoption of improved techniques that are more effective in maintaining zinc in soil solutions.

Comment [NM1]: Reference?

The application of FYM is a potential bio-fortification approach to increase soil zinc availability to plants and thereby its accumulation in wheat grains. Poor soil organic matter usually results in lower availability of Zn in plants. Such a deficiency in zinc causes a significant decrease in the growth and yield of crops. However, information is limited in this aspect. Thus, the study was conducted to define the optimum dose and how the application of FYM in combination with Zn fertilizers in soils affects wheat yields.

Comment [NM2]: Reference?

2. MATERIAL AND METHODS

2.1 Location of experiment

Glass house of Jawaharlal Nehru KrishiVishwaVidyalaya, Jabalpur, India which situated at 23° 13' North latitude, 79° 57' East longitudes and elevation of 393 meter Above Mean Sea Level.

2.2 Soil of the experimental field

The soil of the experimental field belongs to Kheri series, taxonomically Fine, Montmorillonitic, Hyperthermic family of TypicHaplustert, clayey in texture. The soil of the experimental field was neutral in soil reaction, normal in EC, low in available N and medium in P and K.

Comment [NM3]: Soil determination needs to be harmonized with the WRB classification.

2.3 Pot house experiment using wheat as a test crop

The test crop wheat GW-366 was sown manually as per the recommended practices. About 4 kg soil was placed in clean earthen Pot and mix it with three FYM levels and three zinc levels. Samples were collected from all treatments and analyzed for available zinc. There were viz., different FYM levels that is 0, 5 and 10 kg ha-1 treatments having different zinc levels that is 0, 5 and 10 kg Zn ha-1 with two replications to see the effectiveness FYM with zinc levels on growth, dry matter production and Zn composition of wheat.

2.4 Soil and plant analysis:

Representative soil samples were collected using a core sampling tool from each pot to determine the nutrient status of the soil after the harvest of the crop. The samples were air dried, ground, and passed through a 2 mm sieve and analyzed for organic carbon by Walkey and Black's method (1934) [17] available N by the Alkaline permanganate method (Subbiah and Asija, 1956) [18], available P by the extraction of soil with 0.5 M $NaHCO_3$ (pH 8.5), and the color intensity spectrophotometrically (Olsen et al., 1954) [19], available K is extracted with 1N ammonium acetate (pH 7.0) and estimated by a flame photometer. The available Zn status was analyzed in a suitable aliquot of DTPA extract with the help of an atomic absorption spectrophotometer (Varian AAS-240) Lindsay and Norvell (1978) [20]. Plant samples were collected at maturity for determination of the uptake of Zn. The oven-dried plant samples were finely ground in a stainless-steel Willey mill and digested with a HNO_3:$HClO_4$ (4:1) di-acid mixture for the determination of Zn content as per the procedure given by Jackon (1973) [21].

2.5 Statistical analysis

In order to test the significance of variation in experimental data obtained for various treatment effects, the data were statistically analyzed as described by Panse and Sukhatme (1985) [22]. The critical differences were calculated to assess the significance of the treatment mean wherever the 'F' test was found significant at the 5 percent level of probability. To elucidate the nature and magnitude of treatment effects, summary tables along with SEm+ and CD (P = 0.05) were given.

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Comment [NM4]: In this chapter, it is necessary to list all studied parameters with their full name and abbreviations.

3. Result and Discussions

3.1 Plant height

The result given in Table 1 revealed that the highest mean plant height (57.95 and 65.75 cm) was recorded with 5 t FYM ha-1 + 10 kg Zn ha-1 application, which was significant over control (42.75 and 53.44 cm) while at par with sole application of 5 kg Zn ha-1 (56.60 and 65.70 cm) at 45 and 60 DAS, respectively. Further, it is apparent from data that the plant height of 30.60 cm was recorded at sole application of 5 t FYM ha-1 which was found statistically at par with combined application of 5 t FYM ha-1 +5 kg Zn ha-1, 10 t FYM ha-1 + 5 or 10 kg Zn ha-1. Thus, it is obvious from the data that 5 t FYM ha-1 +10 kg Zn ha-1 is the most suitable one for growth point of view because contributing to additional growth compared to control and other treatments. The results are also in agreement with the findings of Malav and Patel [23].

3.2 SPAD

The findings showed in Table 1 revealed that the highest mean SPAD (40.64) was recorded with 10 t FYM ha-1 +10 kg Zn ha-1 application which was significant over control (28.19) and rest of the treatments but at par with 5 t FYM ha-1 +10 kg Zn ha-1 (39.66) at 21 DAS. However, at 45 DAS, the SPAD value of 42.52 was recorded at sole application of 10 t FYM ha-1 which was found statistically superior to all rest of the treatments. Thus, it is obvious from the data that 10 t FYM ha-1+10 kg Zn ha-1 is the highest SPAD reading at 21 DAS, but it was not steady after wards (45 DAS). However, sole application of 10 t FYM ha-1 showed the highest SPAD reading indicated that the highest chlorophyll formation and FYM plays an important role in nitrogen metabolism and development of pigment biosynthesis.

Yield attributes

3.3 Spike length

The findings showed in Table 2 revealed that the highest mean spike length (7.65 cm) was recorded with 5 kg Zn ha-1 which was significantly superior to all the treatments. Further, the application of 10 kg Zn ha-1 gave 6.95 cm spike length. However, spike length (6.75 cm) was recorded at 10 t FYM ha-1 +10 kg Zn ha-1 which was found statistically on par with 5 t FYM ha-1 and 10 t FYM ha-1 with 5 and 10 kg Zn ha-1. Thus, 5 kg Zn ha-1 might improve the catalytic activity in anther of wheat that increased spike length. Similar findings were reported by Zia et al., (2007) [24] Shaheen et al., (2007) [25], Ziaeyan and Rajaeia, (2009) [26] and Abbas et al., (2009) [27].

3.4 Spike weight

Among the treatments, the highest mean spike weight was recorded with 5 kg Zn ha-1 which was significantly superior to control and other rest of the treatments (Table 2). Further, the sole application of 5 t FYM ha-1, significantly increased the spike weight (0.72 g) and equal with combined application of 5 t FYM ha-1+5 kg Zn ha-1 and 10 t FYM ha-1 +10 kg Zn ha-1 addition (0.72 and 0.69 g). Zn is required for the biosynthesis of plant growth regulator (IAA) and for carbohydrate and N metabolism which leads to high yield and yield components.

3.5 No. of grains per spike

The data in table 2 revealed that the highest mean number of grains per spike (23.90) was recorded with 5 kg Zn ha-1 application which was significantly superior to all the treatments. Further, the sole application of 10 kg Zn ha-1 and 5 t FYM ha-1 and combined application of 10 t FYM ha-1 +5 kg Zn ha-1 (18.90, 18.25 and 18.50) enhanced significantly but found statistically on par each other except 5 t FYM ha-1. Zn has a key role in increasing the activities of enzymes [28], helps in growth hormones production [29], formation of spike and assimilates translocation to seed.

Yield

3.6 Grain weight

The result in table 2 revealed that the highest mean grain weight (2.50 g pot-1) was recorded with 5 t FYM ha-1 +5 kg Zn ha-1 which was at par with 5 t FYM ha-1, 5 kg Zn ha-1 and 10 t FYM ha-1+10 kg Zn ha-1 but significant superior to all the rest of treatments. The result showed that the use of FYM in combination with Zn produce the highest grain weight which might be due to the involvement of the Zn in activation of enzymes [30]. Harris et al. (2007) [31] and Karim et al. (2012) [32] also observed an increase in grains weight with each incremental level of Zn. These results are in accordance with the findings of Niyigaba et al. (2019) [33].

3.7 Dry matter production (DMP)

The highest DMP of 7.12 g pot-1 was recorded with 5 kg Zn ha-1 which was significantly superior to all the treatments (Table 2). Further, 5 t FYM ha-1 application enhanced the DMP significantly (6.11 g pot-1) but at par with 5 t FYM ha-1 + 5 kg Zn ha-1, 5 t FYM ha-1 + 10 kg Zn ha-1 and 10 t FYM ha-1 + 10 kg Zn ha-1 addition (5.58, 5.60 and 5.58 g pot-1). The combined application of FYM and Zn brings higher DMP of wheat than control which might be due to better absorption of water and nutrientsfrom the soil and applied fertilizers [34]. These findings are supported by Duan et al. 2014 [35], Sheoran et al. 2017 [36] and Sultana et al. 201 [37].

3.8 Zn content and uptake

The findings showed in Table 3 revealed that the highest Zn content (48.95 mg kg-1) in grain of wheat was recorded with 10 kg Zn ha-1 followed by 5 t FYM ha-1 +10 kg Zn ha-1 (44.45 mg/kg) and both were significantly superior to all the treatments. Further, 5 kg Zn ha-1 application increased Zn (41.63 mg/kg) which was significantly superior to rest of the treatments but at par with 5 t FYM ha-1 + 5 kg Zn ha-1 (39.80 mg/kg).

The highest Zn uptake (99.53 and 98.82 µg pot-1) by grain of wheat was recorded with 5 t ha-1 FYM + 5 kg Zn ha-1 which was significantly superior to all the treatments but at par with 5 kg Zn ha-1 (98.82 µg pot-1). Combined application 5 t ha-1 FYM +10 kg Zn ha-1 showed 83.56 µg Zn pot-1 uptake by grain which was significant superior to all the treatments but at par with 10 t ha-1 FYM +10 kg Zn ha-1 (77.66 µg pot-1). The combined application of FYM and Zn might be due to intermediates/metabolites of decomposition of FYM that hold Zn in forms available to plants or release of Zn mobilizing compounds such as phytosiderophores from roots, and induction of polypeptides involved in Zn uptake and translocation to shoots [15].

3.9 P content in grain

P content in grain was found to be non- significant (Table 3). However, the application of different treatments were found significant for P content in straw. The maximum P content in grain (0.37%) was found at10 t FYM ha-1 + 10 kg Zn ha-1, followed by 5 kg Zn ha-1, 10 kg Zn ha-1 and the minimum value found in control (0.32%). With the application of FYM the pH of soil decreased, and it make the P available to the crops [38]. FYM and mineral P have significantly enhanced the available phosphorus portion of soil and soil fertility [39, 40]. FYM released P slowly and it will take up by the plant at the time of its need [41].

3.10 Soil fertility status

The data (Table 4) indicated that the highest pH was noted at combined application of 5 t FYM ha-1 + 10 kg Zn ha-1 which was found statistically at par with 10 t FYM ha-1 + 5 kg Zn ha-1, 5 t FYM ha-1 + 10 kg Zn ha-1, 5 t FYM ha-1 + 5 kg Zn ha-1 and 10 t FYM ha-1. The decrease in soil pH with addition of FYM is due to organic acids in the organic manures [42,43]. The result was contradictory with combined application of FYM and Zn but the fact that the decomposition of organic matter resulted in the production of low molecular organic acid like humic and fluvic acids, acetic, formic, oxalic, lactic, propionic, malic, citric, and aconitic acids [44]. FYM have a better structure and may contain humic acid, growth hormones and high microbial population resulted into increased CO2 concentration in soil arising from microbial activity and decomposition of native organic matter. The CO2 in contact with water forms carbonic acid which creates acidity [45]. The EC was significantly increased with 5 t FYM ha-1 + 10 kg Zn ha-1 application over control but at par with 5 t/ha FYM + 5 kg Zn ha-1. Addition of FYM increase the organic acids in the soil which react with the sparingly soluble salts already present converting them to soluble salts [45]. Similar findings were reported by Singh et al. 2016 [46] and Banerjee et al. 2011 [47].

The highest OC was recorded with 10 t ha-1 FYM + 5 kg Zn ha-1 addition (11.88 g kg-1) which was at par with 10 t ha-1 FYM + 5 kg/ha Zn. Further, the SOC content of 9.75 g kg-1 which was found in 5 t FYM ha-1 +5 kg Zn ha-1 and 10 t FYM ha-1 +10 kg Zn ha-1 and both were at par with 5 t FYM ha-1 and 10 kg Zn ha-1 application. The highest Olsen-P was analyzed at 5 t FYM ha-1 +10 kg Zn ha-1 which was significantly over control but at par with 5 t FYM ha-1 +5 kg Zn ha-1 application.

The DTPA Zn in the control soil was 0.32 mg kg-1 and 10 kg applied Zn ha-1 (0.63 mg kg-1) and 5 t FYM ha-1 +10 kg ha-1 Zn (0.67 mg kg-1) was found at the end of the experiment. FYM forms multi-dentate complex which greatly enhances the Zn solubility Stevenson and Cole 1999). to affect the pH perturbations as happened in our case the soil pH decreased with the addition of FYM resulting increase in Zn availability. As soil pH decreases, Zn must compete with the extra H+ and Al3+ for positions on the exchange sites, solubility of Zn increases in the soil solution and a greater proportion is present as highly available free metal ions in the soil solution [48, 49]. Almas et al. 2000 [50] observed the addition of organic matter increased the solubility of Zn through the formation of soluble organo-metallic complexes. Catlett et al. 2002 [51] concluded that binding of Zn2+ with OM has a significant positive impact on its solubility in fine silty neutral to alkaline calcareous soils. CaCO3 in calcareous soils can lead to Zn precipitation as ZnCO3, but ZnCO3 is soluble, hence more available. According to Lindsay 1979 [52] minerals like ZnO (zincite) and $ZnCO_3$ (smithsonite) are too soluble to persist in soils.

Conclusion

Zinc deficiency is a global human malnutrition problem that affects people whose diets are based on wheat. In conclusion, the application of 5 t FYM ha-1 +10 kg Zn ha-1 produced significantly better results for the plant height. The SPAD reading at 10 t FYM ha-1+10 kg Zn ha-1 at 21 DAS afterward it was the highest at sole application of 10 t FYM ha-1. However, 5 kg of Zn ha-1 application enhanced yields attributes. 5 t FYM ha-1 + 5 kg Zn ha-1 showed the highest mean grain weight, and 10 kg Zn ha-1 application increased the Zn content (48.95 mg kg-1) in grain of wheat while Zn uptake (99.53 µg pot-1) by grain of wheat was recorded with 5 t ha-1 FYM + 5 kg Zn ha-1 application. Further it is recommended with 5 t FYM ha-1 +10 kg Zn ha-1 also maintain soil extractable zinc. Hence, the application of 5 kg Zn ha-1 + 5 t FYM ha-1 is recommended to the farmer for increasing the overall Zn content in grain and getting better production of the wheat crop in a Vertisol of central India.

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Table-1 Growth and SPAD values of wheat as influenced by different treatments

Treatment	Plant height (cm)		SPAD	
	45DAS	**60DAS**	**21DAS**	**45DAS**
Control	42.75	53.44	28.19	30.42
5 t FYM ha^{-1}	51.00	58.40	37.56	34.89
10 t FYM ha^{-1}	46.15	48.10	36.88	42.52
5 kg Zn ha^{-1}	56.60	65.70	32.32	34.57
10 kg Zn ha^{-1}	51.00	59.25	31.61	32.80
5 t FYM ha^{-1} + 5 kg Zn ha^{-1}	49.00	55.90	37.77	36.64
5 t FYM ha^{-1} +10 kg Zn ha^{-1}	57.95	65.75	39.66	34.95
10 t FYM ha^{-1} + 5 kg Zn	51.35	58.60	38.49	36.82
10 t FYM ha^{-1} +10 kg Zn ha^{-1}	51.90	59.60	40.64	36.71
SE(m)±	**0.344**	**0.364**	**0.152**	**0.188**
C.D. (P=0.05)	**1.118**	**1.182**	**0.494**	**0.61**

Table-2 **Yield attributes and DMP as influenced by different treatments**

Treatment	**Yield attributes**			**Total DMP (g pot^{-1})**	**Grain wt (gpot^{-1})**
	Spike Length (cm)	**Spike Weight (g)**	**No of grains Spike^{-1}**		
Control	5.40	0.52	13.15	4.10	1.41
5 t FYM ha^{-1}	6.40	0.72	18.90	6.11	2.40
10 t FYM ha^{-1}	6.05	0.41	13.70	3.71	1.13
5 kg Zn ha^{-1}	7.65	0.76	23.90	7.16	2.38
10 kg Zn ha^{-1}	6.95	0.53	18.25	5.03	1.40
5 t FYM ha^{-1} + 5 kg Zn ha^{-1}	6.90	0.72	12.85	5.58	2.50
5 t FYM ha^{-1} +10 kg Zn ha^{-1}	6.15	0.54	16.55	5.60	1.88
10 t FYM ha^{-1} + 5 kg Zn	6.30	0.56	18.50	5.18	1.87
10 t FYM ha^{-1} +10 kg Zn ha^{-1}	6.75	0.69	15.80	5.58	2.22
SE(m)±	**0.143**	**0.01**	**0.1**	**0.129**	**0.077**
C.D.(P=0.05)	**0.465**	**0.031**	**0.32**	**0.42**	**0.251**

Table-3 **Zinc content in wheat as influenced by different treatments**

Treatment	P (%)		Zn (mg kg^{-1})		Uptake of zinc (µg pot^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw
Control	0.32	0.04	27.35	3.80	49.02	8.65
5 t FYM ha^{-1}	0.35	0.04	30.95	4.80	74.26	17.83
10 t FYM ha^{-1}	0.34	0.09	33.98	10.03	60.66	34.55
5 kg Zn ha^{-1}	0.37	0.07	41.63	10.28	98.82	49.21
10 kg Zn ha^{-1}	0.37	0.05	48.95	9.35	68.30	33.99
5 t FYM ha^{-1} + 5 kg Zn ha^{-1}	0.32	0.07	39.80	6.55	99.53	20.14
5 t FYM ha^{-1} +10 kg Zn ha^{-1}	0.35	0.09	44.45	8.60	83.56	31.87
10 t FYM ha^{-1} + 5 kg Zn ha^{-1}	0.36	0.08	35.75	7.63	66.67	25.29
10 t FYM ha^{-1} +10 kg Zn ha^{-1}	0.37	0.09	35.10	5.58	77.66	18.77
SE(m)±	**0.014**	**0.006**	**0.42**	**0.487**	**2.562**	**3.05**
C.D.(P=0.05)	**NS**	**0.021**	**1.362**	**1.58**	**8.312**	**9.896**

Table-4 **Soil fertility status as influenced by different treatments**

Treatment	Physico chemical properties			Olsen-P (kg ha^{-1})	DTPA extractable Zn (mg kg^{-1})
	pH	EC (dSm^{-1})	OC (g kg^{-1})		
Control	7.40	0.32	5.88	16.84	0.32
5 t FYM ha^{-1}	7.53	0.42	8.13	25.66	0.50
10 t FYM ha^{-1}	7.42	0.35	7.88	22.98	0.40
5 kg Zn ha^{-1}	7.70	0.41	8.75	27.17	0.38
10 kg Zn ha^{-1}	7.74	0.42	7.88	21.15	0.63
5 t FYM ha^{-1} + 5 kg Zn ha^{-1}	7.62	0.52	9.75	34.31	0.36
5 t FYM ha^{-1} +10 kg Zn ha^{-1}	7.75	0.53	11.63	35.19	0.67
10 t FYM ha^{-1} + 5 kg Zn ha^{-1}	7.72	0.36	11.88	26.99	0.47

10 t FYM ha^{-1} +10 kg Zn ha^{-1}	7.69	0.32	9.75	27.09	0.44
SE(m)	**0.028**	**0.03**	**0.574**	**2.1**	**0.034**
C.D.	**0.09**	**0.098**	**1.863**	**6.813**	**0.111**