

# Influence of Sulphur and Boron Fertilization on Yield, Quality, Nutrient Uptake and Economics of Soybean (*Glycine max*) under Upland Conditions

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## Abstract

A three year experiment was conducted during 2007-2009 in India (Manipur) to study the effect of sulphur and boron fertilization on yield, quality and nutrient uptake by soybean under upland condition. The experiment comprises five levels of sulphur (0, 10, 20, 30 and 40 kg sulphur per hectare) and five levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg boron per hectare). The study revealed that yield attributing characters like number of branches per plant, pods per plant and 100 seed weight and yield were increased with the application of sulphur and boron as compare to control. The overall result revealed that application of 30kg sulphur per hectare and 1.5 kg boron per hectare were found to be the optimum levels of sulphur and boron for obtaining maximum yield attributes, yield, oil and protein content, total uptake of sulphur and boron, net return, cost and benefit ratio of soybean under upland condition as compare to other levels of sulphur and boron respectively.

**Keywords:** Sulphur, Boron, Soybean, Protein content, Oil content

## 1. Introduction

Soybean [*Glycine max* (L.) Merrill.] is a leguminous crop rich in high quality protein (40-42 %), oil (18-20%) and other nutrients like calcium, iron and glycine. It is a good source of isoflavones and therefore it helps in preventing heart diseases, cancer and HIVs (Kumar, 2007). So it has established its potential as an industrially and economically viable oilseed crop in the world. Because of its high nutritional value and myriad form of uses, it is recognized as 'Golden Bean'. In India, soybean has emerged as an important oilseed crop. It is estimated that the crop has been sown in 8.85 million hectares and is likely to produce 9.47 million tonnes of soybean in 2007 (Anonymous, 2007). Although, national research and development system has developed varieties with much higher yield potentials (3.5 to 4.0 tonnes per hectare) and national level demonstrations have established an average yield level of 1.8 tonnes per hectare under real farm conditions, but the major constraint for low soybean productivity is unbalanced nutrition (Anonymous, 1980 and 2000; Jain, 1986; Tiwari, 2001; Joshi and Bhatia, 2003). Unless soybean is provided with required nutrient input to produce sufficient biomass it does not yield high (Singh *et al.*, 2006).

Sulphur plays a pivotal role in various plant growth and development processes being a constituent of sulphur containing amino acids and other metabolites. It is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium. The role of sulphur in the seed production of soybean has been reported by several investigators (Dubey and Billore, 1995; Fontanive *et al.* 1996 and Shrivastava *et al.* 2000). Among the fertilizer elements sulphur requirement of oilseed crops is quite high as compared to other crops (Das and Das, 1994). Application of sulphur improved nitrogenase activity, nitrogen fixation, plant dry matter and quality of soybean grain in sulphur deficient soil (Kandpal and Chandel, 1993). Kedar Prasad and Rajendra Prasad (2003) found that sulphur at 30 kg per hectare treated pea plants had higher number of grains per plant which was 24.18% higher than the control one. In soybean Bhuiyan *et al.* (1998) found that application of sulphur at 20 kg per hectare produced the highest seed yield, but Mohanti *et al.* (2004) reported sulphur at 30 kg per hectare produced the highest seed yield. Sulphur is involved in the synthesis of fatty acids and also increases protein quality through the synthesis of certain amino acids such as cysteine, cysteine and methionine (Havlin *et al.* (1999).

Singh and Singh (1995) observed that application of 20 kg zinc oxide per hectare and 30 kg Sulphur per hectare independently and significantly increase number of pods per plant and number of seeds per pod of soybean. Kandpal and Chandel (1993) observe that application of sulphur consistently increase the protein and oil contents in grain of soybean resulting maximum content of protein as well as oil at 30 kg per hectare as gypsum. Singh and Aggarwal (1998) found that among the sources of sulphur, gypsum produced significantly higher pods per plant and seed per pod of black gram. Singh *et al.* (1999) reported that potassium sulphate was significantly better than elemental sulphur and pyrite but remained on par with gypsum in production of pods per plant and seeds per pod of Lentil. Among the sources, sulphur applied in the form of gypsum was found superior to pyrite. Yadav *et al.* (1996) studied the response of sesame to different sources of sulphur applied through ammonium sulphate, gypsum, pyrites and elemental sulphur on an alkali and sandy loam soils. Among the sources of sulphur tested ammonium sulphate and gypsum were the best followed by pyrites and elemental sulphur in seed yield.

Field experiment was conducted at the alluvial zone of West Bengal, India during 2000-01 to study the effect of different levels of irrigation and sources of sulphur on the productivity of soybean. The sulphur content and uptake was significantly higher with the application of gypsum as a source of sulphur in soybean (Sounda and Nandini, 2003). Each unit of sulphur added to sulphur deficient soils can augment the supply of the edible oils by 3.0 – 3.5 units (Tandon, 1986). Yogendra *et al.* (1992) reported that on an average the oil content increased by 6.5 percent in soybean, 8.5 percent in mustard, 5.1 percent in groundnut, 36 percent in sunflower and 7.3 percent in rai due to sulphur application through low analysis fertilizers or other sources.

Boron is an essential micronutrient for plants. Among micro-nutrients, boron has found a wider use for agronomic and horticultural crops. Boron is associated with one or more of the following processes: calcium utilization, cell division, flowering and fruiting, water relations, and catalyst for certain reactions (Berger, 1949; Sprague, 1951). Oplinger *et al.* (1993) reported that 0.28 kg boron per hectare applied as foliar increased soybean yield by 3% when 29 trials conducted on boron sufficient soils in the Midwest. Touchton *et al.*, (1980) noted that soybean yield responded positively and nominally to boron fertilization at three of nine site years in Georgia and suggested that environmental conditions probably influence weather soybean response positively or not at all to boron fertilization. Although environmental conditions may play an important role in soybean response to boron fertilization, soybean leaf boron concentrations were sufficient (>25 mg boron per kg) as reported by Touchton *et al.*, 1980.

Several studies have reported that soybean (Touchton and Boswell, 1975), cotton (*Gossypium hirsutum* L.) (Roberts *et al.*, 2000), peanut (*Arachis hypogaea* L.) (Davis and Rhoades, 1994), and alfalfa (*Medicago sativa* L.) (Mortvedt and Woodruff, 1993) yields may respond positively to pre-plant incorporated or post-emergence foliar applications of boron. Boron application rate, rather than application strategy, seems to be the most important factor determining the response of crops grown on boron-deficient soils. Compared with the unfertilized control, Touchton and Boswell (1975) reported that soybean yields were increased from 0 to 4% from application of 0.28 to 1.12 kg boron per hectare and reduced by 6 to 10% from 2.24 kg boron per hectare. The trifoliolate leaves of the unfertilized control contained only 10 mg boron per hectare which is below the critical level of 20 mg boron per kg (Mills and Jones, 1991). While boron requirement for optimum plant nutrition are low compared with those of primary nutrients, the need for boron is especially significant in flowering and seed development.

Much of the boron fertilization research conducted with soybean has examined boron fertilization for the purposed of increasing soybean yield potential by increasing branching (Schon and Blevins, 1990), pod set (Reinbott and Blevins, 1995; Weaver *et al.*, 1985) and various physiological processes that may contribute to higher seed yields (Reinbott and Blevins, 1995), specially for soybean grown in high yielding environments (Touchton *et al.*, 1980). Boron deficiency or excess affects the growth and yield of the crop. It plays an important role in cell differentiation and development, translocation of photosynthates and growth regulators from source to sink and growth of pollen grains thereby marked increase in seed yield of crops (Sakal *et al.*, 1991). Dusting of 2 kg borax per hectare on sunflower heads during seed filling stage was effective in improving the seed filling by 25 per cent (Ahmed Khan *et al.*, 1990). Gormus (2005) reported significant response to foliar boron treatment over the control on clay soil having 0.40 mg per kg boron concentration in Adana, Turkey. Studies by Schon and Blevins (1987) at the University of Missouri demonstrated that foliar applied boron could stimulate yield by increasing pods on lateral branches, seed number, and overall seed yield. Boron is involved in the synthesis of protein (Sauchelli, 1969) and oil (Malewar *et al.*, 2001). Earlier works mark the evidence that application of boron influenced the yield components. Tripathy *et al.* (1999) conclusively suggested that application of boron increased pod per plant. Cell wall strength, cell division, fruit and seed development and sugar transport are plant functions related to boron. Havlin *et al.* (1999) also reported that flowering and fruit development were restricted by a shortage of boron.

Non-judicious use of chemical fertilizers, intensive cultivation of crops, higher cropping intensity and limited use of organic matter are the most possible causes for sulphur deficiency limiting soybean yields. Many research works have been done on nitrogen, phosphorus and potash fertilizers for rice and other crops. But few works have been carried out on the effect of sulphur and boron on rice and other crops, although it has been experimentally proved that sulphur and boron are very much conducive to increase the production of soybean in different parts of Bangladesh as well as many parts of the world. With the above mentioned facts in mind, the study have been undertaken to investigate the effect of sulphur and boron on yield attributes, yield and quality of soybean.

## 2. Materials and Methods

Field experiments were conducted for 3 consecutive years at the Agricultural Research Station of Central Agricultural University, Imphal during 2007-2009 under All India Coordinated Research Project on Soybean. The soil was clay loam in texture with pH (5.4), organic carbon (0.54 per cent), total nitrogen (0.076 per cent), available phosphorus (18.18kg per hectare), available potash (178.4kg per hectare), available sulphur (15 ppm) and available boron (0.55ppm). The treatment consisted of five levels of sulphur (0, 10, 20, 30 and 40 kg per hectare) and five levels of boron (0, 0.5, 1.0, 1.5 and 2 kg per hectare). The experiment was laid out in a factorial randomized block design with three replications. The source of sulphur and boron was gypsum (18 per cent sulphur) and borex (11per cent boron). Sulphur and boron were applied as per treatment along with the recommended dose of fertilizer nitrogen (20 kg per hectare), phosphorus (60 kg per hectare) and potash (40kg per hectare) as basal through urea, di-ammonium phosphate and muriate of potash respectively. Soybean seeds were inoculated with *Bradyrhizobium japonicum* culture at 5g per kg seed after treating with bavistin at 2.5g per kg seed before sowing the plot area was 20.4m<sup>2</sup> (4 x 3.6m) and seeds of soybean cultivar JS 335 was sown on 2<sup>nd</sup> June, 5<sup>th</sup> June and 3<sup>rd</sup> June, 2007, 2008 and 2009 respectively in rows 45 cm apart and 10 cm between plants. Intercultural operations were done as and when necessary. The crop was harvested on 10<sup>th</sup>, 12<sup>th</sup>, and 8<sup>th</sup> October, 2007, 2008 and 2009 respectively.

### 2.1 Growth Characteristics

Plant height and number of braches per plant were recorded at the time of maturity.

## 2.2 Yield and Its Components Characteristics

Yield and its components such as number of pods per plant, number of seeds per plant, seed index, grain yield, straw yield and harvest index were determined at maturity stage.

## 2.3 Chemical Analysis

Grain samples from each plot were dried at 70°C for constant weight and ground for determination of Total nitrogen, oil, sulphur and boron contents.

### 2.3.1 Determination of Soil pH

The pH of soil was estimated by using glass electrode Systronic pH meter with 1:2.5 soil: water suspension method (Jackson, 1973).

### 2.3.2 Estimation of Organic Carbon of Soil

Organic carbon of the soil was estimated by Walkley and Black's Method (Khanna and Yadav, 1979).

### 2.3.3 Estimation of Available Nitrogen of Soil

Available nitrogen of the soil was estimated by Alkaline Permanganate Method (Khanna and Yadav, 1979).

### 2.3.4 Determination of Available Phosphorous

Available phosphorus was estimated by Bray's and Kurtz No.1 method (Jackson, 1973).

### 2.3.5 Estimation of Available Potassium

Available potassium was estimated by Flame photometer method (Jackson, 1973).

### 2.3.6 Estimation of Sulphur

Available sulphur of soil was extracted with 0.15 percent calcium chloride and the soluble sulphate estimated turbidimetrically on a colorimeter using spectrophotometer at 340nm. Total plant sulphur was determined by turbidimetric method using barium chloride and gum acacia gelatin (Tandon, 1993).

### 2.3.7 Estimation of Boron

The available boron in soil sample was determined by adopting Hot Water Soluble Boron Method as described by Berger and Truog, 1939. Boron in plant extract was analyzed colorimetrically by using carmine in sulphuric acid system (Berger and Truog, 1939).

### 2.3.8 Estimation of Oil

The oil content of soybean seeds was estimated by adopting Soxhlet Ether Extraction method (Sadasivam and Manickam, 1996).

### 2.3.9 Estimation of Protein

Total nitrogen content of soybean grain was determined by Micro-Kjeldahl method as recommended by the Association of Official Analytical Chemists (AOAC, 1975), with modifications. Nitrogen contents were multiplied by dry matter-based factor 5.71 to determined total protein content (Sadasivam and Manickam, 1996).

### 2.3.10 Nutrient Uptake

Nutrient uptake was calculated by multiplying the sulphur and boron content of soybean grain and stover with their respective yield.

## 2.4 Statistical Analysis of Data

All the data pertaining to the present investigation were statistically analyzed as per the method described by Gomez and Gomez (1984). The statistically significance of various effects was tested at 5 per cent level of probability.

## 3. Results and Discussion

### 3.1 Effect of Sulphur

#### 3.1.1 Effect of Sulphur on Yield Attributes

The data in Table 1 revealed that the different yield attributing characters of soybean like number of branches per plant, pods per plant and 100 seed weight were significantly influence by different levels of sulphur. Application of sulphur at 30 kg per hectare produced significantly higher number of branches per plant, number of pods per plant and maximum 100 seed weight of soybean over other levels except 40kg per hectare. It might be due to the function of sulphur which plays a pivotal role in various plant growth and development processes

being a constituent of sulphur containing amino acids. With increased supply of sulphur, the process of tissue differentiation from somatic to reproductive, meristematic activity and development might have increased, resulting in increase in number and size of leaves. Similar finding was also reported by (Mengel and Kirkby, 1987). Among the fertilizer elements sulphur requirement of oilseed crops is quite high as compared to other crops (Das and Das, 1994). The above results are in conformity with the results of Joshi and Billore (1998) who reported a gradual increase in these yield attributes of soybean with increasing levels of sulphur. Chaubey *et al.* (2000) observed that numbers of primary branches, pods per plant, plant height and 100 kernel weight of groundnut were significantly higher by the application of sulphur.

### 3.1.2 Effect of Sulphur on Yield

The effect of different levels of sulphur nutrition on soybean seed and straw yield was found to be significant. The highest seed yield (1973 kg per hectare) was obtained by application of 30 kg sulphur per hectare, which might be due to the cumulative favourable effect of higher number of branches and pods per plant and higher seed index of soybean (Table 1). Stover yield was increased with the increase in levels of sulphur. Stover yield was significantly higher (2235 kg/ha) with the application of sulphur at 30 kg per hectare over other levels except 40 kg per hectare. Similarly, harvest index was also highest (46.52) with the application of 30 kg sulphur per hectare. As in soybean, sink lies in leaves, when supply of sulphur is optimum, greater translocation of photosynthates occur from leaves to the site that is seed. The sum total effect will be higher seed yield. Similar results were reported by Kumar *et al.* (1992), (Mengel and Kirkby, 1987), and Sarkar *et al.* (2002).

### 3.1.3 Effect of Sulphur on Total Uptake of Sulphur

Uptake of sulphur by grain showed a significant variation with the application of different levels of sulphur (Table 2). The highest sulphur uptake was found when sulphur was applied at 30kg per hectare and the lowest from no sulphur application. The above results revealed that with the increase in sulphur level increases the uptake due to high sulphur content and high grain yield. These results are in agreement with those of Ganeshamurthy (1996) who reported that sulphur significantly increased the sulphur uptake. Similar result was also found by Chand *et al.* (1997) in mustard. The total sulphur uptake by soybean was found to be at par with the application of 30 kg per hectare and 40 kg per hectare (Table 3).

### 3.1.4 Effect of Sulphur on Protein and Oil Content

Seed protein and oil content was significantly influenced by different levels of sulphur (Table 3). Application of sulphur at the rate of 30kg and 40kg per hectare produced the highest protein and oil content of soybean seed and the lowest was in control. It might be due to involvement of sulphur in the synthesis of fatty acids and also increases protein quality through the synthesis of certain amino acids such as cysteine, cysteine and methionine. It is evident from the results that sulphur had remarkable influence on protein and oil content. Similar finding was also reported by (Havlin *et al.*, 1999) and Kandpal and chandel (1993).

### 3.1.5 Effect of Sulphur on Economics

Net return was increased with increase in the levels of sulphur. The net return obtained from the application of 30 kg sulphur per hectare was found to be at par with 40 kg per hectare. It might be due to increase in grain yield with the increase in levels of sulphur. The cost and benefit ratio is significantly higher with the application of 30 kg per hectare over other levels of sulphur. This result shows that the level of sulphur (30 kg per hectare) significantly influenced on the yield of soybean and ultimately increases the benefit of soybean grower.

## 3.2 Effect of Boron

### 3.2.1 Effect of Boron on Yield Attributes

Boron has a marked influence on yield attributing characters like number of branches per plant, pods per plant and 100 seed weight. The yield attributing characters were increased with the increase in boron levels upto 1.5kg per hectare then decreases at 2.0 kg per hectare. It might be due to the role of boron in cell differentiation and development, translocation of photosynthates and growth regulators from source to sink. The increase in number of branches due to boron fertilization was also reported by Schon and Blevin (1990). Tripathy *et al.* (1999) also conclusively suggested that application of boron increased pods per plant in groundnut. Havlin (1999) reported that flowering and fruit development were restricted by a shortage of boron.

### 3.2.2 Effect of Boron on Yield

The effect of different levels of boron nutrition on seed and stover yield was found to be significant. The seed yield was significantly higher (1831kg per hectare) when the crop received 1.5 kg boron per hectare and the lowest (880 kg per hectare) from control. The lowest in control plot might be due to boron deficiency. Results

are in accordance with that of Singh *et al.* (2003), who documented that crop yields, in general, have been promoted by regular application of boron. Chowdhury *et al.* (2000) also reported that seed yield of cowpea increased significantly with the increase in boron application. Stover yields produced by the application of 1.5kg per hectare and 2.0 kg per hectare were found to be at par but significantly higher over other levels (Table 1). It might be due to increase in plant height and number of branches per plant as a result of cell wall strength, cell division and sugar transport which are plant functions related to boron. The similar trend was also observed on harvest index.

### 3.2.3 Effect of Boron on Total Boron Uptake

Boron had significant variation in relation to boron uptake by soybean (Table 3). The highest boron uptake (0.135 kg per hectare) was achieved by the application of 1.5kg boron per hectare and the lowest (0.044 kg per hectare) from control. In this study it might be concluded that boron uptake was influenced by boron application. The increase in uptake may be due to the increase in level of boron application in the field and high grain yield. The results are in concurrent with the findings observed by Kumar *et al.* (1996) who reported that uptake of boron increased due to boron application.

### 3.2.4 Effect of Boron on Protein and Oil Content

The highest protein and oil content was also found from 1.5kg boron per hectare and the lowest from control. It is evident from the results that protein and oil content was influenced by boron fertilization. The increase in protein and oil content might be due to the involvement of boron in the synthesis of protein. Similar findings were also reported by Saucheli (1969), Malewar *et al.* (2001) and Noor *et al.* (1997).

### 3.2.5 Effect of Boron on Economics

Significantly higher cost benefit ratio was also obtained with the application of boron at 1.5 kg per hectare over other levels (Table 3) and the lowest from the control. This result shows that boron could stimulate yield by increasing pods on lateral branches, seed number, and overall seed yield of soybean. Maximum benefit was obtained by increasing the yield with the application of boron at 30 kg per hectare.

## 4. Conclusion

From the above investigation, it can be concluded that sulphur and boron play a vital role in increasing the yield attributing characters and yield of soybean. Application of 30kg sulphur per hectare gave the maximum yield attributes, yield, oil and protein content, total uptake of sulphur and boron, net return, cost and benefit ratio of soybean under upland condition as compare to 0, 10, 20 and 40kg sulphur per hectare. Similar trend was also observed when applied with 1.5kg boron per hectare as compare to 0, 0.5, 1.0 and 2.0kg boron per hectare.

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Table 1. Effect of sulphur and boron on growth, yield attributes and yield of soybean (average for three years)

Treatment	Plant height (cm)	Branches/plant	Pods/plant	100 seed weight (g)	Stover yield (kg/ha)	Seed yield (kg/ha)	Harvest index (%)
S-level(kg/ha)							
0	45.33	2.3	28	12.35	1080	880	44.88
10	53.3	3.5	36	13.01	1430	1217	45.86
20	56.07	4.0	56	13.23	1963	1549	44.17
30	57.27	4.4	74	13.48	2235	1973	46.52
40	56.80	4.3	71	13.46	2222	1966	46.42
<b>C.D. (P=0.05)</b>	3.71	0.22	5.28	0.17	120	86	1.21
B-level (kg/ha)							
0.0	46.87	2.9	38	12.66	1179	931	44.21
0.5	53.07	3.5	52	13.16	1741	1492	45.48
1.0	55.13	3.8	58	13.23	1872	1612	45.96
1.5	57.53	4.2	61	13.26	2109	1831	46.34
2.0	56.20	4.0	57	13.23	2029	1719	45.86
<b>C.D. (P=0.05)</b>	3.71	0.22	5.28	0.17	120	86	1.21
<b>S x B (P=0.05)</b>	NS	0.49	11.76	0.37	266	192	2.70

Table 2. Effect of sulphur and boron application on sulphur and boron concentration and uptake by soybean (average for three years)

Treatment	Concentration in seed		Concentration in stover		Sulphur uptake by		Boron uptake by	
	Sulphur (%)	Boron (ppm)	Sulphur (%)	Boron (ppm)	seed (kg/ha)	stover (kg/ha)	seed (kg/ha)	stover (kg/ha)
S-level(kg/ha)								
0	0.409	20.57	0.811	10.98	3.60	8.76	0.020	10.98
10	0.412	30.05	0.813	11.33	5.02	11.64	0.058	11.33
20	0.413	28.01	0.839	11.41	6.44	16.54	0.079	11.41
30	0.418	36.05	0.857	11.48	8.28	19.26	0.128	11.48
40	0.416	38.14	0.871	11.49	8.22	19.50	0.129	11.49
<b>C.D.(P=0.05)</b>	0.002	0.57	0.004	0.07	0.36	1.00	0.006	0.073
B-level (kg/ha)								
0.0	0.402	20.87	0.803	10.48	3.74	9.47	0.031	10.48
0.5	0.411	30.66	0.843	11.38	6.14	14.81	0.077	11.38
1.0	0.415	32.85	0.841	11.55	6.69	15.91	0.094	11.55
1.5	0.421	33.77	0.849	11.61	7.74	18.05	0.111	11.61
2.0	0.420	34.67	0.855	11.67	7.25	17.47	0.100	11.67
<b>C.D.(P=0.05)</b>	0.002	0.57	0.004	0.07	0.36	1.00	0.006	0.073
<b>S x B (P=0.05)</b>	0.005	1.27	0.01	0.16	0.81	2.24	0.014	0.163

Table 3. Effect of sulphur and boron on total sulphur and boron uptake and economics of soybean (average for three years)

Treatment	Total Sulphur uptake (kg/ha)	Total Boron uptake (kg/ha)	Oil content (%)	Protein content (%)	Net return	Cost: benefit ratio
<b>S-level (kg/ha)</b>						
0	12.36	0.032	20.13	40.13	31182	1: 2.23
10	16.66	0.074	20.16	40.17	44366	1: 2.47
20	22.98	0.102	20.23	40.22	61156	1: 2.80
30	27.54	0.154	20.31	40.58	83060	1: 3.23
40	27.72	0.155	20.31	40.52	84864	1: 2.87
<b>C.D. (P=0.05)</b>	1.22	0.007	0.017	0.044	1872	0.09
<b>B-level (kg/ha)</b>						
0.0	13.21	0.044	20.22	40.26	31478	1: 1.67
0.5	20.95	0.097	20.22	40.32	61347	1: 2.82
1.0	22.60	0.116	20.23	40.35	65813	1: 2.92
1.5	25.79	0.135	20.24	40.36	74863	1: 3.23
2.0	24.71	0.124	20.24	40.34	71129	1: 2.98
<b>C.D. (P=0.05)</b>	1.22	0.007	0.017	0.044	1872	0.09
<b>S x B (P=0.05)</b>	2.72	0.015	NS	NS	4165	0.20