Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.5, No.5, 2015

Determination of Seed Rate and Variety on the Growth and Yield of Teff in Eastern Amhara Region, Ethiopia

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Abstract
Teff seed rate by variety experiment was conducted from the year 2012 to 2013 at Sirinka Agricultural Research station on red and black soil condition. The objective of the experiment was to determine the appropriate seed rate by broadcast planting system of teff for Eastern Amhara Region. The experiment was designed in factorial randomized complete block consisting of six seed rate levels (5, 10, 15, 20, 25 and 30 kg ha^{-1}) and two different growth habit teff varieties (Quncho was selected as high tillering capacity) and (Mecharie was selected as low tillering capacity) a total of 12 treatments with three replications. The result revealed that, the highest grain yield (2527 kg ha^{-1}) with the lowest seed rate 5 kg ha^{-1} was obtained on black soil in 2012. Similarly, the highest grain yield (3067 kg ha^{-1}) with application of 5 kg ha^{-1} seed rate level was recorded of teff in 2013 black soil. Even if grain yield of teff in 2012 on red soil didn't show significant difference between the seed rate levels of 10 to 30 kg ha^{-1}, the highest grain yield (2707 kg ha^{-1}) was obtained with the lowest seed rate (5 kg ha^{-1}) in 2013. Mean combined analysis of the two years data showed for broadcast planting method of teff, Mecharie variety was revealed highly significant grain yield for black soil types and Quncho was recommended to red soil conditions. Seed rate level of 5 kg ha^{-1} teff was recommended for both black and red soil conditions at Sirinka.
Keywords: black soil, broadcast, red soil, seed rate, teff, variety

1. Introduction

Teff (*Eragrostis tef* /zucc./Trotter) belonging to the grass family poaceae, is a C_4, self-pollinated annual grass, 40 – 80cm tall (Dejene *et al*., 2012). It is one of the most important cereal crops in Amhara region that occupies 33.5%, the cultivated land area under cereals and 27.7% of the whole area cultivated to annual field crops by covering about two million hectares of land annually (CSA, 2010). However, productivity of the current cultivars in Amhara region is very low, 12.8 q ha^{-1} under traditional practices (CSA, 2010). Although, research efforts in the last few decades developed important technologies to overcome production constraints and increase productivity (Seifu Ketema, 1993), it has not yet been raised to satisfactory level as compared to its yield potential.

Teff has much or even more food value than the major grains such as wheat, barley and maize. Teff grain contains 14-15% proteins, 11-33 mg iron, 100-150 mg calcium, and rich with potassium and phosphorus nutrients (National Academy Press, 1996). Teff has got many prospects outside of Ethiopia due to its gluten freeness, tolerance to biotic and abiotic stress, animal feed and erosion control quality. Teff has got many prospects outside of Ethiopia due to its gluten freeness, tolerance to biotic and abiotic stress, animal feed and erosion control quality (Sate Sahle, 2012).

Amongst the factors that contributing to low productivity of the crop are lodging, poor crop management practices, low soil fertility, insect pests and weeds are some of the major once. Development of improved and appropriate agronomic practices (seeding rate, seeding methods, seedbed preparation, fertilizer rate and time of application) would greatly contribute for higher productivity of the crop Tarekegne (2010). The most common way of planting teff is by broadcasting method ranged at the seed rate of 25-50 kg ha^{-1}. Due to its high seeding rate the yield of the crop could not expressed as its potential. However, there is some evidence that increase the productivity of the crop by reducing the seed rate levels. These tests were conducted in the off-season under irrigation in DebreZeit Research Center Tarekegne (2010). Similarly reported teff yield could be improved by two to three-folds in lower seed rate levels by broadcast sowing method (personal communication). Therefore, this research was initiated to confirm earlier preliminary findings and to determine appropriate agronomic practices (seed rate levels and varieties of teff) for increasing the productivity of teff on black and red soil types at Sirinka.

2. Materials and Methods

2.1 Description of the Study Area

The experiment was carried out on black and red soils of Sirinka agricultural research station in Eastern Amhara Region, Ethiopia during the main cropping season for two consecutive years (2012 and 2013). Sirinka ARC is located at 11° 45' 00" North latitude and 39 36' 36" East longitude. The altitude of the experimental area is 1850 m a.s.l. at Sirinka. The mean total annual rainfall (which mainly falls in the cropping season of 2012 and 2013) is 1115.3 mm at Sirinka. The rainfall pattern of the area is bimodal and its distribution is erratic; the effective rainy

period extends from June to September, with the peak during July. Mean average temperature is 19.5 °C at Sirinka.

2.2 Experimental Treatments, Design and Procedures

Determination of Seed Rate and Variety on the Growth and Yield of Teff experiment was conducted from the year 2012 to 2013 at Sirinka Agricultural Research Center station on red and black soil conditions. The treatments were six seed rates (5, 10, 15, 20, 25 and 30 kg ha^{-1}) on broadcasting method and two different growth habit varieties (*Quncho* and *Mecharie*) of teff were used in the study. The varieties were selected as the preference of different growth habit teff varieties (*Quncho* was selected as high tillering capacity) and (*Mecharie* was selected as low tillering capacity). Factorial experiment in RCB design with three replications was used. Gross and net plot size was 5m x 3m and 5m x 2m, respectively. Spacing between plots and between replications was 1m and 2m, respectively. The seed was broadcasted by mixing with small size soil particle (filler). The seed was not be covered by soil. Recommended fertilizer rate for the location (100 and 50 kg DAP and Urea ha^{-1}, respectively) was applied. All DAP and half of the Urea was applied at planting. The remaining urea was applied at tillering stage of the crop. All other agronomic practice was done as recommended. Plant height at maturity (cm) (average of 10 plants $plot^{-1}$), number of tillers m^{-2}, number of effective tillers m^{-2}, lodging (%), shoot fly damage, grain and biomass yield were collected as growth and yield parameters of teff.

2.3 Data Analyses

Data of many important growth and yield parameters collected during the experimental periods were purified and arranged for further analysis. The analysis of variance (ANOVA) was carried out for growth and yield parameters of the following statistical procedures appropriate for the experimental design using Statistical Analysis System (SAS) program package version 9.0 (SAS, 2002). Whenever treatment effects were significant at 0.01 or 0.05 level of significance error, the means were separated by using the least significant difference (LSD) test procedures at 0.05 probability level of significance.

3. Results and Discussions

Determination of seed rate and variety on the growth and yield of teff was showed highly significant difference ($p<0.01$) between the parameters of plant height, number of tillers m^{-2}, number of effective tillers m^{-2} and biomass yield and significant difference was observed between shoot fly damage and grain yield of teff across years on black soil (Table 5). Similarly, highly significant difference was observed between all the parameters of teff across years on red soil (Table 6). The highest grain yield (2395 kg ha^{-1}) was recorded for the year 2013 as compared to 2012 on black soil (Table 5). On the other hand, the highest grain yield (2228 kg ha^{-1}) was recorded for the year 2013 as compared to the year 2012 on red soil at Sirinka (Table 6).

The result indicated that highly significant differences ($p<0.01$) were obtained in teff seed rate and variety for the main effects of variety such as number of tillers m^{-2}, number of effective tillers m^{-2} and lodging on black soil at Sirinka for the year 2012 (Table 1). Significantly higher grain yield (2344 kg ha^{-1}) was recorded for the variety *Mecharie* in case of black soil for the year 2012 (Table 1). Application of different seeding rates had highly significant differences between number of tillers m^{-2} and number of effective tillers m^{-2} for black soils at Sirinka for the year 2012 (Table 1). Similarly, significant differences were obtained between grain yields of teff on black soils in 2012 (Table 1). The highest grain yield (2527 kg ha^{-1}) with application of 5 $kgha^{-1}$ seeding rate and the lowest grain yield (2026 kg ha^{-1}) with application of 30 kg ha^{-1} seeding rate of teff were recorded on black soil at Sirinka for the year 2012 (Table 1).

On the other hand, there were highly significant differences between main effects of seeding rates such as number of tillers m^{-2}, number of effective tillers m^{-2} and biomass yield for red soil at Sirinka in 2012 (Table 2). Likewise, significant differences were observed between lodging and grain yield with applications of different seeding rates of teff on red soil in 2012 (Table 2).Application of variety had highly significant difference between plant height and significant differences between lodging and biomass yield for red soil for the year 2012 (Table 2). Even if grain yield was showed statistically significant between seed rate levels, there were no significant differences between seeding rates of 10 to 30 kg ha^{-1} for teff grain yield on red soil in 2012. But, the lowest grain yield (1325 kg ha^{-1}) of teff was recorded with application of 5 $kgha^{-1}$ seeding rates on red soil at Sirinka in 2012 (Table 2).

Seed rate by variety of teff showed highly significant differences for the parameters of plant height and biomass yield and significant difference was observed on number of tillers m^{-2} in case of main effects of varieties of teff for the year 2013 on black soil (Table 3).On the other hand, highly significant differences were observed between plant height, number of tillers m^{-2} and effective tillers m^{-2} and grain yield as main effect of seed rate levels of teff on black soil in 2013 (Table3). Similarly, significant differences were recorded between seed rate levels of teff lodging, shoot fly damage and biomass yield. The highest grain yield (3067 kg ha^{-1}) with application of 5 kg ha^{-1} seed rate level and the lowest grain yield (1982 kg ha^{-1}) with application of 30 kg ha^{-1}

seed rates were recorded of teff in 2013 black soil at Sirinka (Table 3).

Seed rate by variety of teff showed highly significant differences for the parameters of plant height, biomass and grain yield and significant difference was observed on shoot fly damage in case of main effects of varieties of teff for the year 2013 on red soil at Sirinka (Table 4). The highest grain yield (2455 kg ha^{-1}) was obtained with application of *Quncho* variety of teff in 2013 on red soil (Table 4). On the other hand, highly significant differences were observed between plant height, number of tillers m^{-2} and effective tillers m^{-2}, shoot fly damage, biomass and grain yield as main effect of seed rate levels of teff on red soil in 2013 (Table 4). The highest grain yield (2707and 2455 kg ha^{-1}) was obtained with application of 5 kg ha^{-1} seed rate level and *Quncho* variety, respectively of teff in 2013 on red soil (Table 4). The lowest grain yield (1826 kg ha^{-1}) was recorded with application of the highest seed rate level of 30 kg ha^{-1} of teff in 2013 on red soil at Sirinka.

Combined analyses of seed rate by variety of teff showed highly significant differences for the parameters of plant height, number of tillers m^{-2} and effective tillers m^{-2} and lodging; significant difference was observed on biomass yield in case of main effect of varieties of teff for the year 2012 and 2013 on black soil at Sirinka (Table 5). On the other hand, highly significant differences were observed between plant height, number of tillers m^{-2} and effective tillers m^{-2}, shoot fly damage and grain yield as main effect of seed rate levels of teff on black soil in 2012 and 2013 (Table 5). Similarly, significant difference was observed between lodging and biomass yield with seed rate levels. The highest grain yield (2797 kg ha^{-1}) was obtained with application of 5 kg ha^{-1} seed rate level of teff in 2012 and 2013 on black soil at Sirinka (Table 5). The lowest grain yield (2004 kg ha^{-1}) was obtained with application of the highest seed rate level of 30 kg ha^{-1} on black soil at Sirinka for the combined year of 2012 and 2013.

Combined analyses of seed rate by variety of teff for the year 2012 and 2013 showed highly significant differences for the parameters of plant height, biomass and grain yield; and significant difference was observed on lodging and shoot fly damage in case of main effect of varieties of teff on red soil (Table 6). The highest grain yield (2081 kg ha^{-1}) was obtained with application of *Quncho* variety of teff on black soil (Table 6). The lowest grain yield (1849 and 1880 kg ha^{-1}) were recorded with application of the highest seed rate level of 25 and 30 kg ha^{-1}, respectively on red soil at Sirinka for the combined year of 2012 and 2013. On the other hand, highly significant differences were observed between plant height, number of tillers m^{-2} and effective tillers m^{-2} and shoot fly damage as main effect of seed rate levels of teff on red soil (Table 6). Similarly, significant difference was observed between lodging and biomass yield between seed rate levels.

In general, shoot fly damage was more sever with lower seed rates than higher seed rate levels, this is because of the plants are more succulent for the pest to enter to the plant parts easily than the higher seed rates both on black and red soil conditions. Number of tillers m^{-2} and effective tillers m^{-2} of teff was increased as the seed rate level decreases (Shiferaw Tolosa, 2012). According to Fanuel Laekemariam (2012), the lowest seed rate level of teff gave the highest grain yield as compared to the highest seed rates on black and red soil condition. The main reason was plant population was increased through number of tillers m^{-2} and effective tillers m^{-2} and vigorous plant height also observed from the study. In addition to this, the lodging percentages of the lowest seed rate levels were becoming low as compared to the highest seed rate levels and finally this contributes to get higher grain yield for teff in broadcast planting system (Chanyalew and Assefa, 2013). Broadcast method of sowing for teff showed highly lodged by using higher seed rate levels than using lower seed rate levels, therefore, using the lowest seed rate level is the best technology in terms of lodging as the main problem in teff production system under broadcast sowing method (Shiferaw Tolosa, 2012).

Quncho variety of teff is more lodged than *Mecharie* variety of teff on both black and red soil conditions. The tallest plant height was recorded on *Quncho* variety of teff on black and red soil conditions. Mecharie variety of teff showed the highest number of tillers and effective tillers on black soil condition and highly susceptible to shoot fly damage on red soil condition as compared to *Quncho* variety of teff. Therefore, *Mecharie* variety is recommended to black soil whereas *Quncho* variety is recommended to red soil condition for Sirinka.

4. Conclusions and Recommendations

The grain yield varies with seed rate levels, variety and soil types for teff broadcast planting system. Black soil is an ideal soil type for teff production as compared to red soil type. Therefore, the selection of appropriate seeding rates and varieties of teff for different soil types is one of the issues to be considered in the future, so as to maintain the grain yield of teff in the region. Grain yield of teff is highly influenced by variety, seed rate and soil types. The variety *Mecharie* is recommended for cultivation as broadcast planting system of teff to black soil conditions while *Quncho* is recommended to red soil conditions at Sirinka. The present results highlight the practical importance of adequate seed rate levels for grain yield of teff production and suggest that application of 5 kg ha^{-1} seeding rate was optimum for broadcast planting system of teff for both black and red soil conditions at Sirinka.

5. Acknowledgements
This research was done with financial support by Sirinka Agricultural Research Center. The authors are grateful to Mr. Abirha Alemu and Mr. Asmamaw Yimer for their technical assistance in managing the experiment and for data collection.

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Table 1. Mean main and interaction effects of seed rate and variety on the growth and yield of teff at Sirinka on black soil 2012
Means within a column followed by the same letter(s) are not significantly different at $P = 0.05$.

Treatments	Plant height (cm)	Number of tillers m^{-2}	Number of effective tillers m^{-2}	Lodging (%)	Shoot fly damage (score 0-5)	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Variety							
Quncho (V1)	111.5	128.3b	102.2b	89.7a	1.6	7467	2150b
Mechare (V2)	110.3	209.1a	170.2a	71.4b	1.7	7167	2344a
$LSD_{0.05}$	ns	38.65	41.13	5.88	ns	ns	172.2
Seed rate							
5 $kgha^{-1}$ (R1)	113.6	236.7a	190.7a	76.7	2.1	7683.00	2527a
10 $kgha^{-1}$ (R2)	112.8	191.3ab	172.7a	80	1.7	6967.00	2236ab
15 $kgha^{-1}$ (R3)	112	237.8a	210.7a	75	1.7	7617.00	2346ab
20 $kgha^{-1}$ (R4)	113.4	139.3bc	97.3b	82.5	1.7	7283.00	2182b
25 $kgha^{-1}$ (R5)	104.7	109c	79.3b	82.5	1.5	7483.00	2165b
30 $kgha^{-1}$ (R6)	108.8	98c	66.7b	86.7	1.5	6867.00	2026b
$LSD_{0.05}$	ns	66.9	71.2	ns	ns	ns	298.3
Variety x Seed-rate							
$LSD_{0.05}$	9.8	ns	ns	ns	ns	ns	ns
CV (%)	5.2	14.8	19.0	10.6	12.1	12.3	11.1

Table 2. Mean main and interaction effects of seed rate and variety on the growth and yield of teff at Sirinka on red soil 2012

Treatments	Plant height (cm)	Number of tillers m^{-2}	Number of effective tillers m^{-2}	Lodging (%)	Shoot fly damage (score 0-5)	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Variety							
Quncho (V1)	108.8a	270	228	36.9a	1.3	6478a	1707
Mechare (V2)	96.8b	255	218	19.6b	1.3	5650b	1784
LSD $_{0.05}$	6.3	ns	ns	13.6	ns	614.4	ns
Seed rate							
5 kgha^{-1} (R1)	102.9	295a	261ab	11.7b	1.3	4533b	1325b
10 kgha^{-1} (R2)	105.6	347a	312a	16.7b	1.3	6250a	1855a
15 kgha^{-1} (R3)	106.7	347a	295ab	30.8ab	1.3	6100a	1816a
20 kgha^{-1} (R4)	104.6	263a	217b	28.8ab	1.3	6467a	1776a
25 kgha^{-1} (R5)	99.5	157b	123c	30.8ab	1.3	6200a	1765a
30 kgha^{-1} (R6)	97.7	166b	131c	50.8a	1.3	6833a	1935a
LSD $_{0.05}$	ns	87.1	76.5	23.6	ns	1064.2	341.2
Variety x Seed-rate							
LSD $_{0.05}$	ns	ns	ns	ns	ns	ns	ns
CV (%)	8.8	15.3	15.5	29.7	12.4	14.7	16.3

Means within a column followed by the same letter(s) are not significantly different at $P = 0.05$.

Table 3. Mean main and interaction effects of seed rate and variety on the growth and yield of teff at Sirinka black soil 2013

Treatments	Plant height (cm)	Number of tillers m^{-2}	Number of effective tillers m^{-2}	Lodging (%)	Shoot fly damage (score 0-5)	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Variety							
Quncho (V1)	137.7a	104.3b	73.8	94.4	1.4	11022a	2407
Mechare (V2)	126.5b	122.7a	87.7	93.6	1.4	10033b	2384
LSD $_{0.05}$	3.7	15.7	ns	ns	ns	685.6	ns
Seed rate							
5 kgha^{-1} (R1)	140.2a	167ab	130.3a	90.8c	2a	11500a	3067a
10 kgha^{-1} (R2)	137.1a	174.7a	133a	93ab	1.8ab	10083bc	2414b
15 kgha^{-1} (R3)	136.8a	143.7b	108.7a	94.2a	1.7abc	11250ab	2548b
20 kgha^{-1} (R4)	130.3b	82.7c	49.7b	96a	1c	10317abc	2172bc
25 kgha^{-1} (R5)	125bc	70.3c	41bc	93.8ab	1c	10183bc	2189bc
30 kgha^{-1} (R6)	123.2c	42.7d	21.7c	96a	1c	9833c	1982c
LSD $_{0.05}$	6.4	27.2	25.1	3	0.8	1187.4	381.3
Variety x Seed rate							
LSD $_{0.05}$	ns	ns	ns	ns	ns	ns	ns
CV (%)	4.0	10.6	17.0	2.7	19.9	9.4	13.3

Means within a column followed by the same letter(s) are not significantly different at $P = 0.05$.

Table 4. Mean main and interaction effects of seed rate and variety on the growth and yield of teff at Sirinka red soil 2013

Treatments	Plant height (cm)	Number of tillers m^{-2}	Number of effective tillers m^{-2}	Lodging (%)	Shoot fly damage (score 0-5)	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Variety							
Quncho (V1)	141.5a	104.1	71.7	86.4	2.1b	12650a	2455a
Mechare (V2)	128.8b	95.6	66.5	84.7	2.6a	11000b	2001b
LSD $_{0.05}$	3.3	ns	ns	ns	0.4	590.5	150.7
Seed rate							
5 kg ha^{-1} (R1)	141.3a	155.3a	119.7a	83.3	4.3a	11950b	2707a
10 kg ha^{-1} (R2)	141.8a	118.7b	84bc	85	3.5b	13100a	2469ab
15 kg ha^{-1} (R3)	135.3b	121.3b	88b	84.2	2.2c	11600b	2276bc
20 kg ha^{-1} (R4)	131.2bc	81.7c	54.7cd	86.7	1.5cd	11833b	2156cd
25 kg ha^{-1} (R5)	132.3bc	76.3cd	44d	86.7	1.3d	11583b	1934de
30 kg ha^{-1} (R6)	129.1c	45.8d	24.2d	87.5	1d	10883b	1826e
LSD $_{0.05}$	5.7	31.2	29.4	ns	0.7	1022.9	261.1
Variety x Seed-rate							
LSD $_{0.05}$	ns	ns	ns	ns	ns	ns	ns
CV (%)	3.5	14.9	23.0	5.8	13.9	7.2	9.8

Means within a column followed by the same letter(s) are not significantly different at $P = 0.05$.

Table 5. Mean main and interaction effects of seed rate and variety on the growth and yield of teff at Sirinka black soil combined 2012 and 2013

Treatments	Plant height (cm)	Number of tillers m^{-2}	Number of effective tillers m^{-2}	Lodging (%)	Shoot fly damage (score0-5)	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Variety							
Quncho (V1)	124.6a	116.3b	88b	92.1a	1.5	9244a	2279
Mechare (V2)	118.4b	165.9a	128.9a	82.5b	1.6	8600b	2364
LSD $_{0.05}$	2.7	20.2	21	3	ns	505.1	ns
Seed rate							
5 kg ha^{-1} (R1)	126.9a	201.8a	160.5a	83.8b	2a	9592a	2797a
10 kg ha^{-1} (R2)	125a	183a	152.8a	86.5ab	1.8ab	8525bc	2325bc
15 kg ha^{-1} (R3)	124.4a	190.8a	159.7a	84.6b	1.7ab	9433ab	2447b
20 kg ha^{-1} (R4)	121.9a	111b	73.5b	89.3ab	1.3b	8800abc	2177cd
25 kg ha^{-1} (R5)	114.8b	89.7bc	60.2b	88.2ab	1.3b	8833abc	2177bcd
30 kg ha^{-1} (R6)	116b	70.3c	44.2b	91.3a	1.3b	8350c	2004d
LSD $_{0.05}$	4.6	35	36.3	5.2	0.5	874.8	256.6
Variety x Seed-rate							
LSD $_{0.05}$	6.5	ns	ns	ns	ns	ns	ns
CV (%)	4.6	13.4	18.2	7.3	16.8	11.9	13.5

Means within a column followed by the same letter(s) are not significantly different at $P = 0.05$.

Table 6. Mean main and interaction effects of seed rate and variety on the growth and yield of teff at Sirinka red soil combined 2012 and 2013

Treatments	Plant height (cm)	Number of tillers m^{-2}	Number of effective tillers m^{-2}	Lodging (%)	Shoot fly damage (score 0-5)	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Variety							
Quncho (V1)	125.2a	187.1	149.9	61.7a	1.7b	9564a	2081a
Mechare (V2)	112.8b	175.4	142.3	52.2b	1.9a	8325b	1892b
$LSD_{0.05}$	3.4	ns	ns	7.2	0.2	468.5	133.3
Seed rate							
5 kg ha^{-1} (R1)	122.1ab	225.3ab	190.5abc	47.5b	2.8a	8242b	2016
10 kg ha^{-1} (R2)	123.7a	232.7a	198a	50.8b	2.4a	9675a	2162
15 kg ha^{-1} (R3)	121ab	234a	191.7ab	57.5ab	1.8b	8850ab	2046
20 kg ha^{-1} (R4)	117.9abc	172.5b	135.7bd	57.8ab	1.4bc	9150a	1966
25 kg ha^{-1} (R5)	115.9bc	116.8c	83.3de	58.8ab	1.3c	8892ab	1849
30 kg ha^{-1} (R6)	113.4c	106c	77.7e	69.2a	1.2c	8858ab	1880
$LSD_{0.05}$	5.9	55.6	54.7	12.5	0.4	811.5	ns
Variety x Seed-rate							
$LSD_{0.05}$	ns	ns	ns	ns	0.6	ns	ns
CV (%)	6.0	17.7	20.9	20.1	13.7	11.1	14.2

Means within a column followed by the same letter(s) are not significantly different at $P = 0.05$.

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