RESEARCH ARTICLE

PRODUCTIVITY AND PROFITABILITY OF INDIAN MUSTARD (*BRASSICA JUNCEA* L.) UNDER SULPHUR LEVELS AND WEED MANAGEMENT PRACTICES

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Received-06.05.2017, Revised-18.05.2017

Abstract: Field investigations were carried out during winter seasons of 2015-16 and 2016-17 at Varanasi to evaluate the effect of sulphur levels and weed management practices on density and dry matter of weeds and crop-weed competition for sulphur in Indian mustard (*Brassica juncea* (L.) Czernj and Cosson). Amongst sulphur levels, minimum weed density and dry matter production was recorded with the application of 60 kg S/ha which was found to be significantly superior to other sulphur treatments. Amongst weed management treatments, the minimum weed density and weed dry matter production was observed with pendimethalin (0.75 kg/ha) + Hand weeding (HW) at 30 DAS and was at par with the hand weeding twice during both the years, and in second year this was statistically similar to oxyfluorfen (0.2 kg/ha) and oxadiargyl (0.1 kg/ha). More seed yield was observed with 60 kg S/ha (2.19 t/ha) in first year, and in second year more yield was associated with 40 kg S/ha (2.07 t/ha). During the first year, maximum seed yield was registered with oxyfluorfen (0.2 kg/ha) amongst herbicidal treatments, and was at par with all treatments except weedy check, fluchloralin (0.75 kg/ha) and oxyfluorfen (0.15 kg/ha), and in the second year highest seed yield was recorded with the hand weeding twice (20 and 40 DAS), and was statistically at par with the oxyfluorfen (0.2 kg/ha), pendimethalin (0.75 kg/ha) + HW at 30 DAS and oxadiargyl (0.1 kg/ha). In main plot treatments, the least nutrient uptake by weeds was recorded with the application of 60 kg S/ha. Within sub-plot treatments, the least nutrient depletion by weed was registered with hand weeding twice during both the years of data and was at par with pendimethalin (0.75 kg/ha) + HW at 30 DAS. Economics revealed that application of 60 kg S/ha gave the maximum net return (` 19,380). However, highest benefit: cost ratio (2.03) was registered with the application of 40 kg S/ha. The highest net return (` 19,950) was observed with the hand weeding twice (` 19,950/ha), and was followed by application of pendimethalin (0.75 kg/ha) + HW at 30 DAS (` 19,850/ha). Maximum benefit: cost ratio (2.06) was recorded with the application of oxyfluorfen (0.2 kg/ha) and was closely followed by pendimethalin (0.75 kg/ha) + HW at 30 DAS (1.91).

Keywords: Economics, Sulphur level, Mustard, Nutrient uptake, Weed management, Yield

INTRODUCTION

India is blessed with diverse agro ecological conditions ideally suited for growing oilseed crops which account 12-15 per cent of the world's oilseed area, 7-8 per cent of oilseed output and 6-7 per cent of the vegetable oil consumption (Hegde, 2009). Oilseeds occupy 27.5 million ha which account for 14% of total cropped area in the country with a production of 24.7 million tonnes, accounting for nearly 5% of the gross national product and 10% of the value of all agricultural products. Rapeseed and mustard rank third in area (21%) and production (23%) after groundnut (*Arachis hypogaea* L.) and soybean (*Glycine max* L. Merr.). The productivity of rapeseed and mustard in the country is quite low (1.15 t/ha) against the world average of 1.40 t/ha (Puri and Sharma, 2006).The average productivity of rapeseed and mustard in India needs to be enhanced up to 2.56 t/ha by 2030 for ensuring edible oil self-reliance (DRMR, 2011). Mustard is one of the most important crops adopted by the farmers in the Eastern Uttar Pradesh region of India. This is a potential crop in winter season due to its wider adaptability and suitability to exploit residual moisture. Sulphur promotes oil synthesis, besides being an important constituent of seed protein, amino acids, enzymes, glucosinolates and chlorophyll (Holmes, 1980). Among the oilseed crops, rapeseed-mustard has the highest requirement of sulphur (Tandon, 1986). Sulphur uptake and assimilation in rapeseed-mustard are crucial for determining yield, oil, quality and resistance to various stresses. Sulphur increases the yield of mustard by 12 to 48% under rainfed, and by 17 to 124% under irrigated conditions (Aulakh and Pasricha, 1988). In terms of agronomic efficiency, each kilogram of S increases the yield of mustard by 7.7 kg (Katyal *et al.*, 1997). It has been estimated that yield depression in rapeseed-mustard due to weed infestation varied from 20-70% depending on the composition and density of weed flora and time of their occurrence (Donovan *et al.*, 2007).

In the past, farmers of Eastern Uttar Pradesh were bound to follow traditional weed techniques such as hand-pulling, hand-hoeing or mechanical hoeing. These techniques, besides being labour and energy intensive and weather dependent, are very difficult to apply due to shortage and high cost of labour. Application of adequate fertilizer to plant crop increases their leaf growth, which facilitates either shading of the soil surface and thus, reduces weed seed germination (Wicks *et al.*, 2012). In the past, little attention has been given to improve mustard

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productivity through integrated weed management in the Indo-Gangetic plains. Therefore, the proposed study was carried out with the objective to develop suitable sulphur and weed management technology for mustard production under the Indo-Gangetic plain region.

MATERIAL AND METHOD

A field trial was conducted during winter (*Rabi*) seasons of 2015-16 and 2016-17 at the Agricultural Research Farm located at the South-Eastern part of Varanasi city at 25°18´ N latitude, 83°03´E longitude and at an altitude of 128.93 m above mean sea level in the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. The soil was sandy clay loam in texture, medium in organic carbon (0.42%), low in available N (195.20 kg/ha) and medium in P_2O_5 (17.51 kg/ha) and K_2O (190.10 kg/ha) content with pH 7.8. The total rainfall recorded during crop growth period was 39.5 and 23.43 mm, minimum temperature ranges from 8 to 12 and 8.9 to 14.8, and maximum temperature 19.2 to 32.6 and 16.2 to 31.3°C during winter 2015 and 2016, respectively. The field experiment was conducted in split-plot design with three replications, having 44 treatment combinations of four sulphur levels *viz.*, 0 kg/ha, 20 kg/ha, 40 kg/ha and 60 kg/ha in main-plot and eleven weed control treatments *viz.*, weedy check, hand weeding twice (20 and 40 DAS), fluchloralin (0.75 kg/ha), fluchloralin (1.25 kg/ha), fluchloralin (0.75 kg/ha) + hand weeding (HW) at 30 DAS, oxyfluorfen (0.15 kg/ha), oxyfluorfen (0.2 kg/ha), pendimethalin (0.75 kg/ha) + HW at 30 DAS, oxadiargyl (0.07 kg/ha), oxadiargyl (0.1 kg/ha), alachlor (0.75 kg/ha) + HW at 30 DAS. Fluchloralin was applied one day prior to sowing of the crop and incorporated immediately into the soil to a depth of 5 cm while oxyfuourfen, pendimethalin, oxadiargyl and alachlor were applied three days after sowing through a manually operated foot sprayer with flat-fan nozzle using 800 liter water/ha. Sulphur was applied in the form of elemental sulphur15 days before sowing by broadcasting followed by incorporation in the soil.

The recommended dose of fertilizer (RDF) was 100, 50, 50 kg N, P_2O_5 and K_2O/ha, respectively for mustard. NPK were supplied through urea, diammonium phosphate (DAP) and muriate of potash (MOP). Full amount of phosphorus and potash and half of nitrogen was applied at the time of sowing. The remaining dose of nitrogen was top dressed at 35 days after sowing. Two quadrates of 25 cm × 25 cm were placed randomly in each plot and weeds within the quadrates were removed and after drying in hot air oven (70 ± 1 °C for 72 hours), weed dry weight was recorded. Mustard cultivar 'RH-749' was sown on 7th November, 2015 and 10th November, 2016, respectively. The seed and straw yield was computed from the harvest of net plot and expressed in ha. Plant and soil samples were analyzed for uptake of nitrogen, phosphorus and potash as per standard laboratory procedures (Jackson, 1973). Available phosphorus was determined by Olsen's method as outlined by Jackson (1973), using spectrophotometer (660 nm wavelength). Available potassium was extracted with neutral normal ammonium acetate and the content of K in the solution was estimated with flame photometer (Jackson, 1973). The experimental data were analyzed statistically by applying the technique of analysis of variance (ANOVA) prescribed for the design to test the significance of overall difference among treatments by the F test and conclusions were drawn at 5% probability level. Benefit: cost ratio (B: C) was obtained by dividing the gross income with cost of cultivation. The effect of treatments was evaluated on pooled analysis basis on growth, yield attributes and yields.

RESULT AND DISCUSSION

The most dominant weed species at experimental site were *Anagallis arvensis, Chenopodium album, Convolvulus arvensis, Centella asiatica, Melilotus indica, Melilotus alba, Medicago polymorpha, Coronopus didymus, Oxalis latifolia, Vicia sativa* and *Rumex* spp. During both the years dicot weeds were predominant in the field. The most prominent weeds of rapeseed were recorded as *Chenopodium album, Chenopodium murale, Anagallis arvensis, Convolvulus arvensis, Euphorbia heliscopia, Medicago polymorpha, Cynodon dactylon, Phalaris minor* and *Asphodalus* spp. (Bhowmik, 2003). Amongst sulphur levels, minimum weed density was recorded with the application of 60 kg S/ha, during both the years (Table 1). This might be due to better growth of crop over weeds and smothering effect of crop vegetative growth over the weeds leading to suppression of weeds population greatly. All weed management treatments significantly reduced the weed density at 60 days after sowing. The minimum weed density was recorded under pendimethalin (0.75 kg/ha) + HW at 30 DAS, and was at par with the hand weeding twice, during both the years, further in second year this was statistically similar with oxyfluorfen (0.2 kg/ha) and oxadiargyl (0.1 kg/ha). Maximum weed infestation was registered with the control, and was closely followed by oxyfluorfen (0.15 kg/ha) and oxadiargyl (0.07 kg/ha). Sulphur levels played significant role in reducing weed dry matter production. Application of 60 kg S/ha significantly reduced the weed dry matter production during both the years. All the weed management practices significantly reduced the weed dry matter compared to weedy check (Table 1). Significantly lower weed dry matter was registered under hand weeding, pendimethalin (0.75 kg/ha) + HW at 30 DAS and alachlor (0.75 kg/ha) + HW at 30 DAS during the first year and pendimethalin (0.75

kg/ha) + HW at 30 DAS and oxyfluorfen (0.15 Kg/ha) during the second year.

Application of 60 kg S/ha and 40 kg S/ha registered significantly more seed yield compared to other levels of fertilizers. During the first year, more seed yield was recorded with 60 kg S/ha (2.19 t/ha) and in the second year more seed yield was associated with the 40 kg S/ha (2.07 t/ha). S (60 kg/ha) gave 45% more mean grain yield over lower sulphur level (20 kg/ha). The higher seed yield due to higher sulphur levels was because of better growth and more translocation of photosynthates from source to sink (Tripathi *et al*., 2011, Rana *et al*., 2005). All the weed control treatments significantly increased the seed yields of mustard over weedy check. During first year, maximum seed yield was registered with oxyfluorfen (0.2 kg/ha), and was at par with all the treatments except weedy check, fluchloralin (0.75 kg/ha) and oxyfluorfen (0.15 kg/ha). In second year, peak seed yield was recorded with hand weeding twice, and was statistically at par with oxyfluorfen (0.2 kg/ha), pendimethalin (0.75 kg/ha) + HW at 30 DAS and oxadiargyl (0.1 kg/ha). Application of herbicidal treatments alongwith hand weeding at 30 DAS gave 32 to 68% more seed yield over weedy check. This was in conformity with the finding of Donovan *et al*. (2007).

Stover yield revealed that sulphur levels gave positive response during both the years of observation. More stover yield was registered with 60 kg S/ha in the first year, and with 40 kg S/ha in the second year. Both the treatments were at par with each other during both the years of experiment, and significantly better than other set of sulphur management practices. The greater strover yield at higher sulphur levels was attributed to increased plant height and leaf area and finally more accumulation of dry matter per plant. This greater straw yield was also concluded by Sah *et al.* (2006). Amongst sub-plot treatments, more stover yield was recorded with hand weeding twice during both the years. However in first year, this was statistically similar with pendimethalin (0.75 kg/ha) + HW at 30 DAS and fluchloralin (0.75 kg/ha) + HW at 30 DAS, and in second year with fluchloralin (1.25 kg/ha), pendimethalin (0.75 kg/ha) + HW at 30 DAS, fluchloralin (0.75 kg/ha) + HW at 30 DAS and alachlor (0.75 kg/ha) + HW at 30 DAS. This might be due to the efficient control of weeds with lower dry matter production of weeds and higher crop growth.

Amongst sulphur treatments, the least nutrient uptake by weed was recorded with the application of 60 kg S/ha. Uptake of nitrogen failed to produce any significant response during both years of study. Uptake of phosphorus gave positive response only in first year and the least nutrient uptake registered with 60 kg S/ha. Uptake of potassium was the least registered with higher sulphur levels *i.e.* 60 kg S/ha during both the years (Table 3). Uptake of sulphur was the least registered with 60 kg S/ha and it was at par with 40 kg S/ha during both the years. Among weed control treatments, maximum uptake of primary nutrients by weed was registered with weedy check. The least nutrient uptake by weed was registered with hand weeding twice during both the years and was at par with pendimethalin (0.75 kg/ha) + HW at 30 DAS. The removal of N, P, K and S by weeds were reduced significantly by various herbicidal and manual weeding treatments and it was almost nil under hand weeding twice, whereas the significantly highest N,P,K and S uptake by weeds were recorded in the weedy check treatments (Table 3). These results confirm the finding of Kaur *et al.* (2013).

Application of 60 kg S/ha registered more nitrogen uptake during both the years. The highest uptake of phosphorus and potassium was recorded with 60 kg S/ha and was statistically at par with 40 kg S/ha during both the years. Application of 60 kg S/ha gave higher uptake of sulphur by the crop during both the years. These observations are in agreement with the findings of Shekhawat *et al.* (2012). Among weed management practices, maximum uptake of NPK was recorded with the hand weeding twice during both the years. Application of pendimethalin (0.75 kg/ha) + HW at 30 DAS gave maximum nitrogen uptake by crops, and was at par with the oxyfluorfen (0.2 kg/ha) and alachlor (0.75 kg/ha) + HW at 30 DAS. Uptake of phosphorus was highest with pendimethalin (0.75 kg/ha) + HW at 30 DAS during the second year. However, it was at par with the oxyfluorfen (0.2 kg/ha) and alachlor (0.75 kg/ha) + HW at 30 DAS during the first year. Potassium uptake was more with pendimethalin (0.75 kg/ha) + HW at 30 DAS during the initial year of observation. However, in the second year this was at par with the fluchloralin (0.75 kg/ha) + HW at 30 DAS and alachlor (0.75 kg/ha) + HW at 30 DAS. Sulphur uptake was maximum with hand weeding twice followed by pendimethalin (0.75 kg/ha) + HW at 30 DAS during the first year. However during the second year, maximum uptake of sulphur was seen with hand weeding twice and it was at par with pendimethalin (0.75 kg/ha) + HW at 30 DAS.

Application of 60 kg S/ha gave maximum net return (`20,850/ha) during first year while in second year, 40 kg S/ha produced maximum net return (`18,650/ha) (Table 2). Mean net return of two years revealed that maximum net return was with 60 kg S/ha (`19,380). However, highest benefit: cost ratio (2.03) was registered with the application of 40 kg S/ha. Among weed management treatments, highest net return (`19,950) was obtained with the hand weeding twice (`19,950/ha), followed by application of pendimethalin (0.75 kg/ha) + HW at 30 DAS (`19,850/ha). Maximum benefit: cost ratio (2.06) was recorded with the application of oxyfluorfen (0.2 kg/ha) and closely followed by pendimethalin (0.75 kg/ha) + HW at 30 DAS (1.91).

Therefore, it may be concluded that application of sulphur at 40 kg/ha along with application of pendimethalin (0.75 kg/ha) plus hand weeding at 30 DAS was found to be best in terms of mustard yield and nutrient uptake by weeds and crop.

Table 1. Effect of sulphur levels and weed management practices on weed density and dry matter in Indian mustard

Treatment	Weed density (no./m^2)		Weed dry matter (g/m^2)	
	2016-17	2017-18	2016-17	2017-18
Sulphur level (kg/ha)				
0	23.1 (534)*	18.9 (358)	28.9	33.2
20	17.3 (300)	19.4 (374)	25.7	27.7
40	12.6 (157)	15.4 (235)	22.3	25.0
60	9.4 (87)	11.2 (125)	21.4	20.2
SEm±	0.31	0.44	0.47	0.65
CD (P=0.05)	0.93	1.31	1.40	1.96
Weed management practice				
Control	27.0 (789)	30.3 (897)	65.3	59.1
Hand weeding (HW) twice (20 and 40 DAS)	9.6 (92)	11.1 (124)	11.3	15.3
Fluchloralin (0.75 kg/ha)	18.3 (336)	21.0 (442)	25.1	28.1
Fluchloralin (1.25 kg/ha)	16.4 (267)	19.3 (373)	19.6	25.4
Fluchloralin (0.75 kg/ha) + HW at 30 DAS	11.2 (125)	16.3 (266)	13.3	19.1
Oxyfluorfen (0.15 kg/ha)	21.4 (456)	19.1 (365)	16.3	13.9
Oxyfluorfen (0.2 kg/ha)	13.4 (178)	12.4 (152)	14.6	18.4
Pendimethalin (0.75 kg/ha) + HW at 30 DAS	10.0 (100)	11.2 (126)	12.0	9.4
Oxadiargyl (0.07Kg/ha)	20.2 (409)	23.7 (561)	21.4	27.3
Oxadiargyl (0.1Kg/ha)	17.3 (300)	15.2 (231)	25.3	20.1
Alachlor (0.75Kg/ha) + HW at 30 DAS	11.1 (123)	12.7 (160)	10.3	16.4
SEm±	0.41	0.56	0.97	1.01
CD (P=0.05)	1.23	1.69	2.91	3.03

Data subjected to square root transformation. *Figures in parentheses are original values.

Table 2. Effect of sulphur levels and weed management practices on seed yield, stover yield and economics

Treatment	Seed yield (t/ha)		Stover yield (t/ha)		Net return* (×10^3 `/ha)		B:C ratio	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Sulphur level (kg/ha)								
0	1.20	1.03	2.97	2.98	8.05	6.98	0.87	0.76
20	1.70	1.58	3.01	3.33	12.11	13.25	1.75	1.68
40	2.07	1.95	4.08	3.98	19.16	18.65	2.10	1.97
60	2.19	1.87	4.51	3.21	20.85	17.91	1.82	1.55
SEm±	0.08	0.05	0.34	0.35				
CD (P=0.05)	0.23	0.14	1.01	1.05				
Weed management practice								
Hand weeding (HW) twice (20 and 40 DAS)	2.22	2.19	4.35	3.78	20.10	19.89	1.86	1.78
Fluchloralin (0.75 kg/ha)	1.52	1.36	3.02	3.08	16.83	14.25	1.25	1.42
Fluchloralin (1.25 kg/ha)	1.86	1.71	3.69	3.52	17.33	16.89	1.23	1.96
Fluchloralin (0.75 kg/ha) + HW at 30 DAS	1.93	1.79	4.01	3.66	19.63	17.06	2.05	1.61
Oxyfluorfen (0.15 kg/ha)	1.62	1.73	3.26	3.18	17.44	16.96	1.55	1.30
Oxyfluorfen (0.2 kg/ha)	2.01	1.91	3.59	3.42	19.02	18.78	2.14	1.98
Pendimethalin (0.75Kg/ha) + HW at 30 DAS	2.09	2.10	3.98	3.54	19.74	19.99	2.02	1.81
Oxadiargyl (0.07 kg/ha)	1.83	1.46	3.43	3.29	17.86	14.98	1.34	1.27
Oxadiargyl (0.1 kg/ha)	1.90	1.93	3.44	3.16	19.54	19.66	2.03	1.98
Alachlor (0.75 kg/ha) + HW at 30 DAS	2.01	1.71	4.01	3.65	19.09	16.86	1.14	1.21
Control	0.93	0.82	2.61	2.98	6.18	5.05	0.73	0.81

SEm±	0.09	0.11	0.19	0.13
CD (P=0.05)	0.26	0.34	0.56	0.39

*Price of mustard seeds (`30.50/kg); urea (`10.90/kg); DAP (`22.0/kg); MOP (`9.75/kg); cost of labour (`162.50/day).

Table 3. Effect of sulphur levels and weed management practices on NPKS uptake by weeds and crop

Treatment	Uptake by weeds (kg/ha)								Uptake by crop (kg/ha)							
	N		P		K		S		N		P		K		S	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Sulphur level (kg/ha)																
0	4.06	4.32	2.80	3.25	10.2	8.95	1.11	1.17	60.2	87.0	14.2	16.0	55.3	66.3	7.8	5.3
20	3.96	3.98	2.98	3.21	9.12	9.65	0.91	0.94	102.3	87.4	21.4	18.9	79.0	63.9	9.4	6.8
40	3.56	3.39	2.31	2.98	7.98	7.89	0.80	0.84	121.6	112.3	30.0	29.6	95.7	78.9	9.3	7.3
60	2.84	3.21	1.90	1.85	6.89	5.69	0.70	0.71	133.4	123.0	33.4	32.1	98.0	89.6	12.9	10.8
SEm±	0.28	0.29	0.04	0.07	0.17	0.24	0.05	0.06	2.67	2.12	1.15	1.72	1.89	3.34	0.38	0.39
CD (P=0.05)	NS	NS	0.12	NS	0.45	0.68	0.13	0.15	8.02	6.34	3.36	5.12	5.62	9.98	0.93	0.95
Weed management																
Hand weeding (HW) twice (20 and 40 DAS)	2.01	2.34	1.39	1.41	7.98	9.18	0.60	0.69	133.0	125.0	28.9	27.0	103.1	111.3	13.1	13.7
Fluchloralin (0.75 kg/ha)	4.98	4.10	2.36	2.98	11.10	10.10	0.86	0.84	107.6	109.3	20.0	21.9	71.2	79.3	11.4	11.5
Fluchloralin (1.25 kg/ha)	4.89	4.95	2.54	3.14	9.89	10.10	0.81	0.89	112.1	108.1	20.1	19.0	80.2	83.0	11.6	11.6
Fluchloralin (0.75 kg/ha) + HW at 30 DAS	3.91	4.11	2.11	3.00	8.91	9.06	0.79	0.80	110.1	105.6	111.9	21.6	20.1	94.0	91.1	11.9
Oxyfluorfen (0.15 kg/ha)	5.52	5.17	3.11	3.91	12.00	13.10	0.91	0.95	104.3	89.6	18.0	15.2	79.1	70.2	10.4	10.5
Oxyfluorfen (0.2 kg/ha)	3.11	3.68	2.81	2.16	9.11	10.20	0.93	0.97	123.1	116.9	26.0	21.9	89.4	82.5	10.6	10.6
Pendimethalin (0.75 kg/ha) + HW at 30 DAS	2.51	2.98	1.55	1.59	8.06	9.01	0.61	0.72	126.8	119.1	27.0	26.9	98.2	95.0	12.9	13.7
Oxadiargyl (0.07 kg/ha)	4.54	5.02	2.88	3.99	12.00	13.10	1.50	1.63	111.3	94.4	20.0	15.8	85.1	84.2	9.3	9.5
Oxadiargy l(0.1kg/ha)	3.91	4.28	2.58	2.91	10.10	11.00	1.56	1.71	114.2	107.3	21.1	21.3	90.9	91.1	9.7	9.7
Alachlor (0.75kg/ha) + HW at 30 DAS	3.71	3.80	1.90	3.10	9.96	10.00	0.64	0.75	120.9	116.9	25.4	19.1	96.0	94.9	12.7	13.5
Control	6.19	7.72	3.98	4.89	24.00	29.40	2.01	2.32	88.2	69.4	15.4	12.4	65.3	53.3	7.6	7.9
SEm±	0.34	0.35	0.15	0.19	0.37	0.44	0.02	0.01	2.84	2.53	0.78	0.66	2.44	2.97	0.04	0.02
CD (P=0.05)	0.99	1.04	0.44	0.57	1.10	1.32	0.03	0.02	8.53	7.58	2.35	1.98	7.33	8.91	0.11	0.06

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