International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(2): 2074-2078

Received: 05-01-2019
Accepted: 08-02-2019

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Agronomic investigations in barley genotypes as influenced by BBF and different integrated nutrient management practices

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Abstract
A field experiment was conducted during *rabi* season of 2013-14 and 2014 -15 in farmers' field at model watershed, Neeralkatti village, Dharwad district of Karnataka to study the "quality of malt barley genotypes as influenced by Integrated nutrient management and *in-situ* moisture conservation practices' in rainfed condition. The treatments comprised of two main plots as land management practices *viz.* L_1: broad bed and furrow (BBF), L_2: farmer's practice (flat bed), two genotypes *viz.* G_1: DWRB – 73, G_2: BH - 902 as sub plots and sub-sub plots consists of five integrated nutrient management practices *viz.* N_1: RDF (50:25:0 N:P_2O_5:K_2O kg ha^{-1} + 7 t ha^{-1} FYM), N_2: 75% N through urea + 25% N through FYM and recommended P through inorganic, N_3 : 50% N through urea + 50% N through FYM and recommended P through inorganic, N_4: 75% N through urea + 25% N through vermicompost and recommended P through inorganic, N_5: 50% N through urea + 50% N through vermicompost and recommended P through inorganic. Significantly higher total dry matter production, productive tillers, grains per spike, test weight and grain yield was obtained with genotype DWRB-73 sown on BBF with the application of RDF (2122 kg ha^{-1}) compared to rest of the treatment. Significantly higher malt recovery (88.5%), higher malt yield (1879 kg ha^{-1}) was observed from grains harvested with genotype DWRB-73 grown on broad bed and furrow along with application of RDF (50:25:0 N:P_2O_5:K_2O kg ha^{-1} + 7 t ha^{-1} FYM) compared to rest of the treatments.

Keywords: Malt yield, malt recovery, productive tillers, grain yield

Introduction

Barley (*Hordeum vulgare* L.) is an ancient cereal crop, which upon domestication has evolved from largely a food grain to a feed and malting grain. It is considered fourth largest cereal crop in the world with a share of 7% of the global cereal production. Annual rainfall in several parts of dry lands is sufficient for one or more crops per year. Erratic and high intensity storms lead to runoff and erosion. The effective rainfall may be 65 per cent or sometimes less than 50 per cent. Hence, soil management practices have to be tailored to store and conserve as much rainfall as possible by reducing the runoff and increasing storage capacity of soil profile. The simple *in situ* moisture conservation technology developed to prevent or reduce water losses and to increase water intake is the Broad Bed and Furrow (BBF) method. This method is effective on black soils. It plays an important role in reducing the velocity when runoff occurs and increases the infiltration opportunity time and excess water is removed in large number of small furrows.

Global area under the crop was nearly 48.60 million hectares with a production of 134.27 million tonnes. The continuous dressing with organic manures alone could match the nutrient requirement of traditional crop varieties, where the demand for nutrients is relatively small, however, it would be inadequate in case of hybrids or improved varieties. The results of long-term fertilizer experiments have clearly shown that balanced application of chemical fertilizers alone, under intensive cropping, does not sustain crop productivity and has resulted in substantial reduction of soil health leading to the depletion of organic matter and availability of micronutrients in soils over years. The energy crisis has resulted into high price index of chemical fertilizers coupled with limited production. The high fertilizer cost, degradation in soil health, lack of sustainability and pollution have led to renewed interest in the use of organic manures as the inclusion of FYM and vermicompost with chemical fertilizers regulates the nutrient uptake, improves crop yields and physical environment of soil.

Material and Methods

A field experiment was conducted during *rabi* season of 2013-14 and 2014 -15 in farmer's field at model watershed, Neeralkatti village, Dharwad district of Karnataka at $15^{0}\ 33^{1}\ 31.61^{11}$ N latitude and of $74^{0}\ 54^{1}\ 39.64^{11}$ E longitude with an altitude of 672 m above the mean sea level on deep black soil. The experiment was laid out in split-split plot design with three replications involving two *in-situ* moisture conservation practices *viz.* L_1: broad bed and furrow (BBF), L_2: farmer's practice (flat bed) as main plots, two genotypes as sub plots *viz.* G_1: DWRB – 73 which is characterised as two row barley with grain/malting ability and G_2: BH - 902 which was characterised as six row barley with fodder and grain ability and five integrated nutrient management practices *viz.* N_1: RDF (50:25:0 $N:P_2O_5:K_2O$ kg ha^{-1} + 7 t ha^{-1} FYM), N_2: 75% N through urea + 25% N through FYM and recommended P through inorganic, N_3 : 50% N through urea + 50% N through FYM and recommended P through inorganic, $N_{4:}$ 75% N through urea + 25% N through vermicompost and recommended P through inorganic, $N_{5:}$ 50% N through urea + 50% N through vermicompost and recommended P through inorganic as sub-sub plots. The soil of the experimental site was medium black clay with pH (7.62), EC (0.54 dS m^{-1}), organic carbon content was (0.52%), available N (260 kg ha^{-1}), P_2O_5 (15 kg ha^{-1}) and K_2O (304 kg ha^{-1}). The mean annual rainfall for the past 62 years at the Main Agricultural Research Station, Dharwad which is nearer to experimental field was 721.0 mm. Rain received during *kharif*-2013 and 2014 helped to store moisture in soil during *rabi* season.

Malting consists of steeping, germination and drying or kilning of cereal grains. It was done on a standard cycle of 126 hrs. Malting was carried out according to EBC (European Brewery Convention) methods with slight modification (Anon, 2013) [3]. It is explained through the help of flow chart. The resulting product is called malt. The dried malt was cleaned by removing the roots and shoots. The malts were milled into flour using attrition mill to pass through 1 mm mesh screen, packaged in plastic containers and stored in wooden cupboard before use (Aniche and Palmer, 1990) [1].

Malt yield was calculated by multiplying malt recovery with respective grain yields and expressed in kg ha^{-1}. The total biomass yield for each net plot was recorded at harvest. After threshing, grains were separated, cleaned and weighed.

Malt recovery was calculated by using formula:

$$\text{Malt recovery (\%)} = \frac{\text{Malt weight (g)}}{\text{Grain sample weight (g)}} \times 100$$

Results and Discussion

Among the *in situ* moisture conservation practices, more number of tillers per m row length and higher dry matter production (Table 1) were observed in crop raised on broad bed and furrow (BBF) at harvest due to higher soil moisture status in BBF (Kadam *et al*., 2000) [7]. Significantly higher grain yield and straw yield (1757 kg ha^{-1} and 3377 kg ha^{-1}, respectively) of barley were observed in broad bed and furrow compared to farmer's practice (Table 2). The yield increase was to the extent of 12.9 and 7.4 percent over farmer's practice. This could be attributed to improved performance of growth and yield parameters through adequate availability of nutrients and soil moisture throughout the growing season, which in turn, favourably influenced physiological processes and build up of photosynthates. The increased yield of barley on BBF was mainly due to significant increase in number of productive tillers per m row length (94.4), grains per spike (30.9) and test weight (48.0 g) compared to farmers' practice. Water stress during the grain filling stage in farmer's practice resulted in lighter grains. Nieuwenhuis and Castaneda (2002) [9] asserted similar views of reduction in 1000-grain weight of rice under moisture stress. Higher grain yield per unit area in BBF was cumulative effect of total dry matter production over its crop growth stages. Reduced lodging of wheat at maturity on raised beds also lead to improved yield attributing characters and yield (Singh and Singh, 2003) [11]. Additional sunlight entering the canopy during maturity stage resulted in better strength of the straw as a result of more drying of the soil around the base of the plant (Hobbs and Gupta, 2003) [5].

One of the key qualities of malting barley, is its ability to germinate rapidly and synchronously. Dormancy can interfere with the rapid and uniform germination of barley, thereby reducing the resultant malt quality. The failure of barley grains to germinate at an acceptable level, *i.e.* > 96 per cent could introduce problems during the malting process (Kumar, 2012) [8]. *In situ* moisture conservation practices significantly influenced malt recovery and malt yield. The broad bed and furrow recorded higher malt recovery and malt yield (82.7% and 1464 kg ha^{-1}, respectively) compared to farmers' practice (78.4% and 1229 kg ha^{-1}, respectively) (Table 2). This can be attributed to the increased moisture in BBF compared to flat bed which helped the plant to undergo physiological and biochemical processes necessary for build-up of malt. Increased moisture enhances the synthesis, accumulation and translocation of the metabolites to the economic parts of the plant.

Among the genotypes, pooled results indicated that genotype DWRB - 73 recorded significantly higher grain yield (1888 kg ha^{-1}) compared to genotype BH - 902 (1415 kg ha^{-1}) (Table 2). The yield increase was to the extent of 33.4 percent over BH - 902. The increased yield of genotype DWRB-73 was mainly due to significant increase in number of productive tillers per m row length (94.7), total dry matter production (277.1 g m^{-1} row length) and test weight (53.0 g) compared to BH - 902. The improvement was to an extent of 11.5 and 52.3 per cent, respectively (Table 2) due to greater genetic ability of variety to translocate the photosynthates to economic part. Other factors which indirectly influenced the grain yield are growth attributes *viz.*, number of tillers and total dry matter production at harvest. Crop yield depends not only on the accumulation of photosynthates during the crop growth and development, but also on it's translocation in the desired storage organs. These intern, are influenced by the efficiency of metabolic processes within the plant (Anjhu George, 2014 and Ramesh *et al*., 2013) [2, 9]. Genotype BH-902 recorded significantly higher straw yield (3311 kg ha^{-1}) compared to DWRB-73 (3200 kg ha^{-1}) due to its ability to produce higher biomass as it is a dual type variety to produce both grain and fodder (Hari Ram *et al*., 2014) [4]. The improvement in the straw yield was to an extent of 3.5 per cent over DWRB-73 (Table 2). It was observed that DWRB-73 genotype partitioned more than 9.1 per cent of its total dry mater production towards the economic parts of the plant.

Malt yield is a critical factor in malting as it reflects the amount of extracts obtainable from the grain. Barley genotypes significantly influenced malt recovery and malt yield. The genotype DWRB-73 recorded higher malt recovery and malt yield (82.8% and 1572 kg ha^{-1}, respectively) compared to the genotype BH-902 (77.9% and 1108 kg ha^{-1}, respectively) (Table 2). This can be attributed to the inherent ability of the genotype (DWRB-73) which helped the plant to undergo physiological and biochemical processes necessary for build-up of malt. Synthesis, accumulation and translocation of the metabolites to the economic parts of the plant was more in this genotype. This difference in malting characteristics could be attributed to their physiological and structural differences. This was because of uniform seed which resulted in more uniform germination, plump kernels for maximum malt extract and relatively low protein that increased extract levels and enhanced beer stability.

Among the integrated nutrient management practices, pooled results showed significantly higher grain yield (1775 kg ha^{-1}) and straw yield (3392 kg ha^{-1}) with application of RDF (50:25:0 N:P_2O_5:K_2O kg ha^{-1} + 7 t ha^{-1} FYM) which was on par with the application of 75% N through urea + 25% N through vermicompost and recommended P through inorganics (1724 kg ha^{-1}grain yield and straw yield 3335 kg ha^{-1}) followed by the application of 75% N through urea + 25% N through FYM and recommended P through inorganics. Whereas, significantly lower grain yield (1521 kg ha^{-1}) and straw yield (3106 kg ha^{-1}) were obtained with the application of 50% N through urea + 50% N through FYM and recommended P through inorganics. The grain yield of barley with RDF was more to an extent of 6.0, 16.7, 3.0 and 13.4 percent over N_2, N_3, N_4 and N_5, respectively. The factors mainly responsible for variation in the grain yield of barley are due to variations in the performance of yield components *viz.*, productive tillers per m row length (97.0), total dry matter production (277.5 g m^{-1} row length), grains per spike (32.7) and test weight (49.1 g) at harvest which was on par with the application of 75% N through urea + 25% N through vermicompost and recommended P through inorganic (Table 2).

Application of RDF (50:25:0 N:P_2O_5:K_2O kg ha^{-1} + 7 t ha^{-1} FYM) recorded significantly higher malt recovery (83.3%) compared to rest of the treatments and it was on par with the application 75% N through inorganics + 25% N through vermicompost and recommended P through inorganics (82.6%) (Table 2). This was due to higher availability of nutrients from both organic and inorganic sources which helped the plant to undergo physiological and biochemical processes for the formation of malt. Malt yield is a key quality indicator because it reflects the amount of beer that can be produced from a given quantity of malt (Table 2).

Under rainfed conditions, the synergistic effects of soil and moisture conservation practices and integrated nutrient management practices are more effective than their individual effects. Significantly higher grain yield was obtained with interaction of genotype DWRB-73 sown on BBF with the application of RDF (50:25:0 N:P_2O_5:K_2O kg ha^{-1} + 7 t ha^{-1} FYM) (BBF x DWRB-73 x RDF, 2122 kg ha^{-1}) compared to rest of the interactions except it was on par with $L_1G_1N_4$, (2060 kg ha^{-1}) *i.e.* genotype DWRB-73 planted on BBF with the application of 75% N through urea + 25% N through vermicompost and recommended P through inorganics. The increase in grain yield with BBF x RDF was due to integrated effect of *in situ* moisture conservation and integrated nutrient management practices and also individual effects of interaction components which might have also contributed for the significance of the interaction. The yield increase in BBF x DWRB -73 x RDF *i.e.*, genotype raised on broad bed and furrow along with application of RDF (50:25:0 N:P_2O_5:K_2O kg ha^{-1} + 7 t ha^{-1} FYM) was attributed to significantly higher dry matter production at harvest, higher number of productive tillers per m row length (108.5, Table 2) and more test weight (62.5 g, Table 2) which was on par with application of 75% N through urea + 25% N through vermicompost and recommended P through inorganics ($L_1G_1N_4$).

Table 1: Productive tillers, total dry matter production, grains per spike and test weight of barley genotypes as influenced by integrated nutrient management under *in situ* moisture conservation practices (pooled data)

	Productive tillers (m^{-1} row length)	Total dry matter production at harvest (g m^{-1} row length)	Grains per spike	Test weight (g)
Main plot (Land management) – L				
L_1	94.4a	276.2a	30.9a	48.0a
L_2	86.0b	256.5b	27.6b	40.5b
S.Em ±	0.30	2.27	0.26	0.32
Sub plot (Genotypes) – G				
G_1	94.7a	277.1a	24.5b	53.0a
G_2	84.9b	253.9b	33.6a	34.8b
S.Em ±	0.40	2.05	0.24	0.40
Sub sub (INM) – N				
N_1	97.0a	277.5a	32.7a	49.1a
N_2	92.0b	267.9b	30.2b	45.8b
N_3	81.7c	253.6c	24.8c	37.9c
N_4	94.5ab	273.4ab	31.5ab	47.4ab
N_5	84.1c	255.2c	26.0c	39.3c
S.Em ±	0.88	2.00	0.43	0.57
Interaction (L x G x N)				
$L_1G_1N_1$	108.5a	300.1a	29.2fg	62.5a
$L_1G_1N_2$	101.3bc	287.9bc	27.0g-i	57.4bc
$L_1G_1N_3$	91.2d-f	273.4de	21.7kl	50.9d
$L_1G_1N_4$	105.0ab	295.7ab	27.9gh	60.5ab
$L_1G_1N_5$	94.4de	277.3c-e	22.3jk	52.7d
$L_1G_2N_1$	95.3de	273.8de	39.6a	43.7ef
$L_1G_2N_2$	89.7f-h	265.2efg	36.5bc	40.6f
$L_1G_2N_3$	80.2kl	256.9fg	31.4ef	32.8g
$L_1G_2N_4$	92.7d-f	269.7de	38.5ab	41.8ef
$L_1G_2N_5$	82.4i-k	251.3g	32.5e	34.1g
$L_2G_1N_1$	96.3cd	280.1cd	26.5g-i	54.4cd

$L_2G_1N_2$	92.4d-f	270.9de	24.7ij	51.0d
$L_2G_1N_3$	81.0j-l	252.7fg	19.3l	43.4ef
$L_2G_1N_4$	93.7de	275.9c-e	25.7hi	52.6d
$L_2G_1N_5$	83.7i-k	257.4fg	20.7kl	44.7e
$L_2G_2N_1$	87.9f-h	256.2fg	35.5cd	35.7g
$L_2G_2N_2$	84.4i-k	247.5g	32.9e	34.3g
$L_2G_2N_3$	74.2m	231.5h	26.7g-i	24.4h
$L_2G_2N_4$	86.5h-j	252.4fg	33.9de	34.8g
$L_2G_2N_5$	75.7lm	235.0h	28.5g	25.7h
S.Em ±	1.76	4.00	0.85	1.14

*The means followed by the same lower case letter(s) in a column do not differ significant by DMRT
DAS: Days after sowing
L_1: BBF G_1: DWRB –73
L_2: Farmer's practice G_2: BH - 902
N_1: RDF (50:25:0 N:P_2O_5:K_2O kg ha^{-1}+ 7 t ha^{-1} FYM)
N_2: 75% N through inorganics + 25% N through FYM and recommended P through inorganics
N_3: 50% N through inorganics + 50% N through FYM and recommended P through inorganics
N_4: 75% N through inorganics + 25% N through Vermicompost and recommended P through inorganics
N_5: 50% N through inorganics + 50% N through Vermicompost and recommended P through inorganics

Table 2: Grain yield, Straw yield, Malt recovery and Malt yield of barley genotypes as influenced by integrated nutrient management under *in situ* moisture conservation practices (pooled data)

	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Malt recovery (%)	Malt yield (kg ha^{-1})
Main plot (Land management) – L				
L_1	1757a	3377a	82.7a	1464a
L_2	1556b	3142b	78.4b	1229b
S.Em ±	32.5	38.4	0.56	33.9
Sub plot (Genotypes) – G				
G_1	1888a	3200b	82.8a	1572a
G_2	1415b	3311a	77.9b	1108b
S.Em ±	13.9	16.1	0.51	16.21
Sub sub (INM) – N				
N_1	1775a	3392a	83.3a	1488a
N_2	1674b	3280b	81.3b	1369c
N_3	1521c	3106c	77.1c	1182d
N_4	1724ab	3335ab	82.6a	1434b
N_5	1565c	3163c	77.7c	1226d
S.Em ±	17.5	19.8	0.37	17.59
Interaction (L x G x N)				
$L_1G_1N_1$	2122a	3456bc	88.5a	1879a
$L_1G_1N_2$	2019b	3341c-e	85.3b	1723b
$L_1G_1N_3$	1854c	3164f-h	82.1cd	1524cd
$L_1G_1N_4$	2060ab	3397b-d	88.3a	1821ab
$L_1G_1N_5$	1909c	3223e-g	82.6c	1579cd
$L_1G_2N_1$	1634cd	3570a	82.6f	1352e
$L_1G_2N_2$	1535de	3455bc	81.0f	1243e
$L_1G_2N_3$	1381f	3279d-f	76.6g	1060f
$L_1G_2N_4$	1591cd	3508ab	82.3f	1311e
$L_1G_2N_5$	1427f	3337c-e	77.6g	1108f
$L_2G_1N_1$	1904c	3221e-g	83.7cd	1597c
$L_2G_1N_2$	1805c	3104g-i	81.4d	1471d
$L_2G_1N_3$	1658d	2941j	76.9e	1279e
$L_2G_1N_4$	1857c	3164f-h	82.3cd	1531cd
$L_2G_1N_5$	1695d	2987ij	77.4e	1313e
$L_2G_2N_1$	1438ef	3321de	78.3g	1126f
$L_2G_2N_2$	1339f	3222e-g	77.5g	1038f
$L_2G_2N_3$	1189g	3043h-j	72.7h	866g
$L_2G_2N_4$	1389f	3270d-f	77.3g	1074f
$L_2G_2N_5$	1230g	3105g-i	73.3h	903g
S.Em ±	35.0	39.5	0.73	1879

*The means followed by the same lower case letter(s) in a column do not differ significant by DMRT
DAS: Days after sowing
L_1: BBF G_1: DWRB –73
L_2: Farmer's practice G_2: BH - 902
N_1: RDF (50:25:0 N:P_2O_5:K_2O kg ha^{-1}+ 7 t ha^{-1} FYM)
N_2: 75% N through inorganics + 25% N through FYM and recommended P through inorganics
N_3: 50% N through inorganics + 50% N through FYM and recommended P through inorganics
N_4: 75% N through inorganics + 25% N through Vermicompost and recommended P through inorganics
N_5: 50% N through inorganics + 50% N through Vermicompost and recommended P through inorganics

Conclusion
Significantly higher number of productive tillers, dry matter production, grains per spike test weight, grain yield and straw yield was recorded with the genotype DWRB - 73 raised on broad bed and furrow along with the application of RDF (50:25:0 N: P_2O_5: K_2O kg ha^{-1} + 7 t ha^{-1} FYM) and it was on par with DWRB - 73 raised on BBF with application of 75% N through urea + 25% N through vermicompost and recommended P through inorganics. *In situ* moisture conservation practices significantly influenced malt recovery and malt yield. Genotype DWRB - 73 raised on broad bed and furrow with the application of RDF (50:25:0 N: P_2O_5: K_2O kg ha^{-1} + 7 t ha^{-1} FYM) recorded higher malt recovery and malt yield.

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