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Effect of concentrated organic manure and plant growth regulator on yield attributes of Barley (*Hordeum vulgare* L.)

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Abstract

A field experiment was conducted during the *Rabi* season of 2024 at Himalayan University, Jollang, Itanagar, to determine the “Effect of Concentrated Organic Manure and Plant Growth Regulator on Yield of barley (*Hordeum vulgare* L.)”. The experiment was laid out in a Randomized Block Design (RBD) with 7 treatments replicated thrice. The experiment included the following treatments i.e. T₁ - control, T₂ - Bone meal + *salicylic acid*, T₃ - Bone meal + *brassinosteroid*, T₄ - Neem cake + *salicylic acid*, T₅ - Neem cake + *brassinosteroid*, T₆ - Mustard cake + *salicylic acid*, T₇ - Mustard cake + *brassinosteroid*. The study recorded significant differences among different treatments. Highest test weight 1000seeds (g) (45.76g), spikelet per spike (41.4) and spike length (13.76cm) were recorded with application of (T₇) Mustard cake + *brassinosteroid*. Lowest test weight (g) (35.76g), spikelet per spike (26.9) and spike length (8.6cm) were recorded with absolute control (T₁). Significantly higher grain yield (4.84 t/ha) and straw yield (5.85 t/ha) was recorded with application of (T₇) Mustard cake + *brassinosteroid* followed by (T₃) Bone meal + *brassinosteroid* (4.24 t/ha and 5.38 t/ha respectively). Significantly lower grain yield (2.54 t/ha) and straw yield (3.54 t/ha) was recorded with absolute control (T₁).

Keywords: Plant growth regulator, Concentrated organic manure, barley, neem cake, mustard cake, bone meal, *salicylic acid*, *brassinosteroid*, test weight, spike length, spikelet per spike, grain yield, straw yield, harvest index.

Introduction

Barley (*Hordeum vulgare* L.) is an ancient cereal grain, which upon domestication has evolved from largely a food grain to a feed and malting grain (Baik and Ullrich, 2008; Pourkheirandish and Komatsuda, 2007) [4, 17]. It belongs to grass family *poaceae*, tribe *triticeae* and genus *Hordeum*, comprising nearly 350 species. Out of which *Hordeum* consists of about 32 species including the wild and cultivated one. Barley is a diploid with 2n: 14 chromosomes. The cultivated barley (*Hordeum vulgare* ssp. *vulgare*) is one of the oldest of the cultivated plants. Barley can grow in a wide range of environments than any other cereal, including extremes of latitude, longitude and high altitude (Vangool and Vernon, 2006) [25]. It is cultivated mainly for human food supply and grown as animal feed, for malt production and human food. It is frequently being described as the most cosmopolitan of the crops and also considered, as poor man's crop because of its low input requirement and better adaptability to drought, salinity, alkalinity and marginal lands (FAO, 2002) [7]. It ranks fifth among cropping rain production in the world after maize, wheat, rice and soybean (Miralles *et al.*, 2013; Soleymani and Shahrajabian, 2011) [16, 22]. Among major cereals, the total cultivated area of barley in the world is 47 million hectares with an annual production of 3136 kg/ha (FAO, 2018) [6]. Barley ranks next to wheat both in acreage and production among *rabi* cereals in India (Tarun *et al.* 2013) [24]. In India, barley is cultivated on about 6.95 lakhs hectare with production of 1743 lakhs tons and productivity of 2508 kg/ha (Anonymous, 2013) [1].

Concentrated organic manures are nutrient-rich amendments that enhances soil fertility, microbial activity, and plant growth in sustainable agricultural systems (Hue *et al.*, 2000) [10]. Neem cake, a by-product of neem seed oil extraction, is rich in nitrogen, phosphorus, potassium,

and trace elements essential for plant growth. It improves soil organic matter content and fosters microbial diversity (Subramanian *et al.*, 2014) ^[23]. Bone meal, a powdered product from animal bones, is a concentrated source of phosphorus and calcium (15-20%) vital for root development and flowering in plants (Wani *et al.*, 2017) ^[26]. Mustard cake, derived from mustard seed oil, after extraction is a good source of N-(4-6%), P-(1-3%), and K-(1-2%), along with several micronutrients. It contains glucosinolates and natural compounds with pesticidal properties, which helps in managing soil pests and diseases (Kumar *et al.*, 2018) ^[13]. The use of mustard cake also improves soil water retention and organic carbon levels, enhancing soil health (Singh *et al.*, 2004) ^[21].

Plant hormones have been studied for a long time due to their strong link with the regulation of growth and development in plants. *Brassinosteroids* (BRs) are a class of polyhydroxylated steroid hormones that play a crucial role in regulating plant growth, development, and stress responses (Clouse *et al.*, 1996) ^[5]. *Brassinosteroids* are known to promote photosynthesis, nutrient uptake, and antioxidant activity, which improve plant growth and stress tolerance (Awan and Khan, 2023) ^[3]. According to Yang *et al.* (2019) ^[27], *brassinosteroids* (BRs) may be a useful phytohormone to support phytoremediation. Plant species contain *brassinosteroid* in large quantities, which play a part in regulating the growth and development of plants. In order to increase plant growth and development, *brassinosteroids* are involved in metabolism; encourage cell division, cell elongation along with important physiological functions including photosynthesis and antioxidant system. *Salicylic acid* is a phenolic plant hormone that is known to enhance photosynthesis, promote seed germination, and regulate stomatal closure, contributing to overall plant resilience and productivity (Hayat *et al.*, 2010) ^[9]. *Salicylic Acid* plays an essential role in the regulation of plant growth and development, photosynthetic rate, ion uptake and transport, stomatal conductance and transpiration (Khan *et al.* 2003) ^[12].

Materials and Methods

The experiment was conducted during the *Rabi* season of 2024 at Himalayan University in Itanagar. The Crop Research Farm is located in Jollang on the university campus, situated at 27.14 N latitude and 93.62 E longitude, at an altitude of 320 metres above sea level. The site belongs to the Eastern Himalayan Region, and the agro-climatic zone falls under the sub-tropical zone of Arunachal Pradesh. Soil Samples drawn randomly from 0 to 15 cm depth were analysed for physical and chemical properties. The soil was sandy loam and chemical analysis indicate that soil is acidic in reaction, medium in organic carbon, high in nitrogen, low in phosphorus and medium in potassium. The barley variety used was RD-2503. The experiment was laid out in a Randomized Block Design (RBD) with seven treatments and three replications. The plot size was 3 m × 3 m with a spacing of 20 cm × 10 cm. The treatments were as follows:

1. T₁: Control
2. T₂: 100% RDF + Bone Meal + *Salicylic Acid* (100 ppm)
3. T₃: 100% RDF + Bone Meal + *Brassinosteroid* (0.1 ppm)
4. T₄: 100% RDF + Neem Cake + *Salicylic Acid* (100 ppm)
5. T₅: 100% RDF + Neem Cake + *Brassinosteroid* (0.1 ppm)
6. T₆: 100% RDF + Mustard Cake + *Salicylic Acid* (100 ppm)
7. T₇: 100% RDF + Mustard Cake + *Brassinosteroid* (0.1 ppm)

Results and Discussion

The data pertaining to yield attributes such as spike length, spikelet per spike, test weight, grain yield, straw yield and

harvest index are presented in the following tables. Significant variation was observed among the treatments. The treatment T₇ (mustard cake + *brassinosteroid*) outperformed other treatments, followed by T₃ (bone meal + *brassinosteroid*) and T₅ (neem cake + *brassinosteroid*). These results reflect higher efficiency of *brassinosteroid* when combined with various organic manures. Similar findings were reported by Awan and Khan (2023) ^[3] where combined application of *brassinosteroid* and organic fertilizers showed improved yield attributes in cereal crop.

Table 1: Effect of treatments on spike length (cm) of barley.

Treatment	Spike length (cm)
T ₁ - Control	8.66
T ₂ - Bone Meal + <i>Salicylic Acid</i>	10.23
T ₃ - Bone Meal + <i>Brassinosteroid</i>	12.53
T ₄ - Neem Cake + <i>Salicylic Acid</i>	9.70
T ₅ - Neem Cake + <i>Brassinosteroid</i>	11.73
T ₆ - Mustard Cake + <i>Salicylic Acid</i>	11.23
T ₇ - Mustard Cake + <i>Brassinosteroid</i>	13.76
F test	S
S.Ed (±)	0.08
CD (P=0.05)	0.17

The spike length recorded at harvest, is presented in table 1. The data shows that there was a significant effect of different treatments on the spike length of barley.

Among treatments, significantly higher spike length (13.76 cm) were observed with T₇ treatment (Mustard cake + *Brassinosteroid*) which remained on par with application of T₃ treatment (Bone meal + *Brassinosteroid*) (12.53 cm), T₅ (Neem cake + *Brassinosteroid*) (11.73 cm) and T₆ (Mustard cake + *Salicylic acid*) (11.23 cm). Whereas, the significantly lower spike length (8.66 cm) were recorded with the absolute control (T₁).

The increased spike length observed in T₇ treatment (mustard cake + *brassinosteroid*) can be attributed to the synergistic impact of organic amendment and plant growth regulator. Mustard cake enhances soil nutrient availability by enriching organic matter and providing essential nutrients like nitrogen and phosphorus, leading to improved root development and nutrient uptake efficiency (Sangeetha and Baskar, 2016) ^[20]. Simultaneously, *brassinosteroids* play a crucial role in promoting cell elongation, vascular differentiation directly influencing spike elongation (Zhang *et al.*, 2014) ^[28]. The combined effect of mustard cake and *brassinosteroid* creates an optimal growth environment, significantly contributing to observed increase in spike length in barley.

Table 2: Effects of treatments on no. of spikelet per spike of barley.

Treatments	Spikelet per spike
T ₁ - Control	26.9
T ₂ - Bone Meal + <i>Salicylic Acid</i>	32.0
T ₃ - Bone Meal + <i>Brassinosteroid</i>	37.7
T ₄ - Neem Cake + <i>Salicylic Acid</i>	30.5
T ₅ - Neem Cake + <i>Brassinosteroid</i>	35.4
T ₆ - Mustard Cake + <i>Salicylic Acid</i>	33.7
T ₇ - Mustard Cake + <i>Brassinosteroid</i>	41.4
F test	S
S.Ed (±)	0.24
CD (P=0.05)	0.52

The number of spikelet per spike recorded at harvest is presented in table 2. The data shows that there was significant effect of different treatments on the number of spikelet per spike.

Among treatments, significantly higher spikelet per spike was observed in T₇ treatment (Mustard cake + *Brassinosteroid*) i.e. (41.4) which is at par with T₃ treatment (Bone meal + *Brassinosteroid*) i.e. (37.76), T₅ treatment (Neem cake + *Brassinosteroid*) i.e. (35.43). whereas, the significantly lower spikelet per spike (26.9) was recorded with the absolute control (T₁).

The probable reason for higher spikelet per spike of barley in T₇ (Mustard cake + *Brassinosteroid*) could be due to the sustained nutrient release from mustard cake and hormonal stimulation by *brassinosteroids*. *Brassinosteroids* are known to regulate reproductive development and enhance assimilate partitioning to spikes, which can potentially increase spikelet formation (Zhang *et al.*, 2014) [29]. Organic manures improve nutrient availability necessary for meristem differentiation (Sangeetha and Baskar, 2016) [20].

Table 3: Effect of different treatments on test weight of barley.

Treatments	Test Weight (g)
T ₁ - Control	35.76
T ₂ - Bone Meal + <i>Salicylic Acid</i>	38.50
T ₃ - Bone Meal + <i>Brassinosteroid</i>	42.76
T ₄ - Neem Cake + <i>Salicylic Acid</i>	37.26
T ₅ - Neem Cake + <i>Brassinosteroid</i>	41.50
T ₆ - Mustard Cake + <i>Salicylic Acid</i>	40.26
T ₇ - Mustard Cake + <i>Brassinosteroid</i>	45.76
F test	S
SEd (±)	0.02
CD (P=0.05)	0.05

The test weight (g) recorded at harvest, is presented in table 3. The data shows that there was a significant effect of different treatments on test weight (g).

Among treatments, significantly higher test weight (45.76g) were observed with T₇ treatment (Mustard cake + *Brassinosteroid*) which remained on par with application of T₃ treatment (Bone meal + *Brassinosteroid*) (42.76g), T₅ treatment (Neem cake + *Brassinosteroid*) (41.5g) and T₆ (Mustard cake + *Salicylic acid*) (40.26g). Whereas, the significantly lower test weight (35.76g) were recorded with the absolute control (T₁).

The probable reason for higher test weight with T₇ treatment (Mustard cake + *Brassinosteroid*) is primarily due to *Brassinosteroids* which enhances grain filling resulting in higher test weight. Similar findings were shown by Prusakova *et al.* (1995) [18].

Table 4: Effect of treatments on grain yield of barley.

Treatments	Grain yield (t/ha)
T ₁ - Control	2.54
T ₂ - Bone Meal + <i>Salicylic Acid</i>	3.20
T ₃ - Bone Meal + <i>Brassinosteroid</i>	4.24
T ₄ - Neem Cake + <i>Salicylic Acid</i>	3.05
T ₅ - Neem Cake + <i>Brassinosteroid</i>	3.87
T ₆ - Mustard Cake + <i>Salicylic Acid</i>	3.51
T ₇ - Mustard Cake + <i>Brassinosteroid</i>	4.84
F test	S
SEd (±)	0.01
CD (P=0.05)	0.02

The grain yield (t/ha) recorded at harvest, is presented in table 4. The data shows that there was a significant effect of different treatments on the grain yield (t/ha).

The maximum grain yield at harvest (4.92 t/ha) was recorded with T₇ (Mustard cake + *Brassinosteroid*) followed by T₃ (Bone

meal + *Brassinosteroid*) (4.31 t/ha), T₅ (Neem cake + *Brassinosteroid*) (3.93 t/ha) and T₆ (Mustard cake + *Salicylic acid*) (3.59 t/ha). The lowest grain yield (2.50 t/ha) was recorded with absolute control (T₁).

The probable reason for higher grain yield in T₇ (Mustard cake + *Brassinosteroid*) is primarily due to the combination of mustard cake (essential nutrient release, rich in sulphur) and *brassinosteroids* which enhances physiological processes such as photosynthesis and carbohydrate metabolism resulting in better grain filling and higher yields. Similar findings were reported by Li *et al.* (2017) [15] who reported enhanced grain filling and yield in cereals treated with *brassinosteroids*.

Table 5: Effect of Treatments on straw yield of barley.

Treatments	Straw yield (t/ha)
T ₁ - Control	3.54
T ₂ - Bone Meal + <i>Salicylic Acid</i>	4.32
T ₃ - Bone Meal + <i>Brassinosteroid</i>	5.38
T ₄ - Neem Cake + <i>Salicylic Acid</i>	4.08
T ₅ - Neem Cake + <i>Brassinosteroid</i>	4.94
T ₆ - Mustard Cake + <i>Salicylic Acid</i>	4.59
T ₇ - Mustard Cake + <i>Brassinosteroid</i>	5.85
F test	S
SEd (±)	0.02
CD (P=0.05)	0.04

The straw yield (t/ha) recorded at harvest, is presented in table 5. The data shows that there was a significant effect of different treatments on the grain yield (t/ha).

The maximum straw yield at harvest (5.95 t/ha) was recorded with T₇ (Mustard cake + *Brassinosteroid*) followed by T₃ (Bone meal + *Brassinosteroid*) (5.46 t/ha), T₅ (Neem cake + *Brassinosteroid*) (5.01 t/ha) and T₆ (Mustard cake + *Salicylic acid*) (4.67 t/ha). The lowest straw yield (3.52 t/ha) was recorded with absolute control (T₁).

The higher straw yield observed in T₇ (mustard cake + *brassinosteroid*) can be attributed to enhanced vegetative growth due to combined effects of organic amendments and plant growth regulator. Mustard cake provides sustained release of essential nutrients, improving organic matter and nutrient availability, which directly supports better shoot development. While *brassinosteroid* enhance cell division, cell elongation, and overall biomass accumulation by regulating hormonal balance and metabolic activities. Such findings were also reported by Kandil *et al.* (2016) [11] who demonstrated that organic amendments improve shoot biomass by enriching soil nutrient profiles. Additionally, Anuradha *et al.* (2018) [2] reported that *brassinosteroid* positively influence vegetative growth by stimulating photosynthesis and water-use efficiency, contributing to increased straw yield.

Table 6: Effect of treatments on Harvest index of barley.

Treatments	Harvest Index
T ₁ - Control	41.80
T ₂ - Bone Meal + <i>Salicylic Acid</i>	42.58
T ₃ - Bone Meal + <i>Brassinosteroid</i>	44.04
T ₄ - Neem Cake + <i>Salicylic Acid</i>	42.77
T ₅ - Neem Cake + <i>Brassinosteroid</i>	43.94
T ₆ - Mustard Cake + <i>Salicylic Acid</i>	43.34
T ₇ - Mustard Cake + <i>Brassinosteroid</i>	45.31
F test	S
SEd (±)	0.08
CD (P=0.05)	0.17

The harvest index (%) recorded at harvest, is presented in table 6. The data shows that there was a significant effect of different treatments on the harvest index (%).

The highest harvest index (45.31%) was recorded with T₇ (Mustard cake + *Brassinosteroid*) followed by T₃ (Bone meal + *Brassinosteroid*) (44.04%), T₅ (Neem cake + *Brassinosteroid*) (43.94%) and T₆ (Mustard cake + *Salicylic Acid*) (43.34%). The lowest harvest index (41.80%) was observed with absolute control (T₁).

The probable reason for higher harvest index with T₇ (Mustard cake + *Brassinosteroid*) maybe due to the direct relationship between grain yield and HI, where increased grain output directly boosts the index. Studies by Anuradha *et al.* (2018) [2] found that *brassinosteroids* enhance reproductive development and improve grain yield, thus contributing to a higher harvest index.

Conclusion

The study suggested that treatment T₇ (mustard cake + *brassinosteroid*) in barley variety RD-2503 showed the highest spike length (13.76 cm), spikelet per spike (41.4), test weight (45.76 g), grain yield (4.84 t/ha), straw yield (5.85 t/ha) and harvest index (45.31%) respectively. Moreover, it also showed the highest net return (₹1,11,664) and B:C ratio (5.22) across all other treatments. Thus, it can be concluded that combining mustard cake with *brassinosteroid* has the maximum potential to maximize yield quality of barley RD-2503.

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