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Brown Manuring a Reliable Method of Weed Control and Source of Nutrients in Direct Seeded Rice (DSR)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: This review provides an overview of the reliability and utilization of SBM on the DSR system. And its effectiveness in the real world. Effective weed and nutrient management are crucial for optimizing rice production while minimizing environmental impacts. The BM or specifically SBM has emerged as a valuable method for both weed and nutrient management in rice cultivation.
Methodology: Simply said, brown manuring is a "no-till" variation of green manuring that uses a selective herbicide to desiccate the crop prior to flowering rather than cultivating it. In accordance with this method, green manure crops are produced alongside the crop while being eradicated with herbicide. The plants' leftovers are left standing in the field alongside the primary crop without integration or in-situ plowing until the leftovers begin to break down in the soil. Along with weed control due to its shadow impact, organic manure is helpful to add. Brown manuring signifies the application of a post-emergence herbicide most prominently 2,4-d to green manure leaves which results in the loss of chlorophyll and browning of the leaves. The sustainability of crop yields depends on effective fertilizer management. Only when all possible nutrient sources are integrated and crop needs are met then only yield sustainability can be determined. Organic manures can be quite helpful in this regard. But because these manures are heavy and deficient in nutrients, a

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replacement is necessary. Another option for providing nutrients to crops from organic sources is green manure, but this option has some drawbacks because it is primarily used with rice crops, which need 45 to 60 days from seeding to decomposition with ideal temperature and moisture levels.

Results: Brown manuring as a method for integrated nutrition management is the remaining viable choice. In addition to being useful for weed control and enhancing soil health, brown manuring is well capable of providing all the nutrients needed by the crops.

Keywords: BM: brown manuring; SBM: Sesbania brown manuring; 2,4-d; no-till; soil health; organic manure.

1. INTRODUCTION

After corn, rice is the second-most significant cereal crop in the world. In the most recent harvesting year, milled rice production reached around 510 million metric tonnes worldwide. The majority of the world's rice crop has historically been produced in Asian nations. China was the world's top producer of paddy rice in 2021, followed by India and Bangladesh, according to the most recent government statistics, with a production volume of over 212 million metric tonnes. In 2021-2022, roughly 510.3 million metric tonnes of milled rice were used globally. In 2021-22, China was the world's largest consumer of milled rice, using almost 155 million metric tonnes annually. With 103.5 million metric tonnes of rice consumed during the same period, India came in second to China [1]. The human population is increasing every day and feeding them is becoming an integral part of the modern farming system and that is why production must not go down. There are many problems that arise while growing rice like weeds infestation, decreasing water table, lack of proper nutrient management, etc which need to be taken care of to get more output. In order to save water and labor costs we recently started practicing a new method of rice production which is direct-seeded rice where we sow rice directly into the soil in a straight line using a seed driller providing it with proper irrigation from time to time to maintain the proper growth of the rice crop. Many studies indicate that (DSR) performs well in mild water stress conditions [2]. This shows that (DSR) needs much less water than transplanted rice. Effective weed control indicates the success of direct-seeded [3] Rice Nutrition is the primary factor when we talk about rice production. Integrated nutrient management (INM), a method of crop production that is effective and environmentally friendly, involves the integration of all organic, natural, and inorganic sources of nutrients [4]. Rice that is dry-seeded and receives alternate wetting and drying is more susceptible to weed competition than rice that has been transplanted. Therefore, weed management is a serious concern for farmers. The best method for controlling weeds appears to be integrated weed management, which uses pesticides, cultural practices, and biological control [5]. Therefore intercropping of green manure crops may have a dual advantage by providing biomass and controlling the weeds at the same time. We can use both leguminous and non-leguminous crops for example Niger, wild indigo and sun hemp, dhaincha respectively. Brown manuring is just a "no-till" variation of green manuring that uses a selective herbicide to desiccate the crop prior to flowering rather than cultivating it. This method calls for growing green manure crops alongside the crop and using pesticides to eradicate them. The plant residues are left standing in the field with the primary crop without incorporation or in-situ plowing until their residue decomposes in the soil. *Sesbania* spp. and rice are typically grown together under brown manuring practices, and after about 25 days of co-culture, when the dhaincha plants have reached a height that surpasses the rice plants, a weedicide called 2, 4-D is used to kill the Sesbania plants. Sesbania plants will start to look brown and eventually die after being sprayed for 4-5 days. As leaves fall to the ground, they will provide mulch and smother weeds. It destroys Sesbania, not rice because it is a selective herbicide. The down-knocking effect is what is meant by this [6]. Therefore weed management practices are very important.

2. EFFECTS OF BROWN MANURING ON GROWTH AND YIELD OF DIRECT SEEDED RICE

We all know that organic manures are very good for crop growth and soil health, but diversification is very relevant in agriculture improving new methods and utilizing them to find out new results which can change the face of modern agriculture is very important. Brown manuring is

one of those new methods which is being used to eradicate weeds from the rice field maintaining the soil health and at the same time providing a good amount of nutrients that is required by the rice crop to continue its overall growth and get optimum yield. Proving this statement an experiment conducted in Nepal shows that spraying of herbicide bispyribac gave a higher straw yield (5 t ha^{-1}). However, it remained statistically at par with the BM *sesbania* (4.83 t ha^{-1}) similar results were seen in the case of grain yield too [7]. Another study shows that replacing 25% of nitrogenous fertilizer with brown manuring in direct-seeded rice resulted in an increase in plant height by 1.57%, effective tiller number by 9.09% and grain yield by 7.91% when compared to farmer's practice [8]. A combination of butachlor 1.25 kg ha^{-1} + brown manuring + 2,4-D 0.5 kg ha^{-1} gave the highest grain and straw yield measuring (4.36 t ha^{-1} and 6.11 t ha^{-1}). However, it remained statistically at par with complete weed-free conditions, possibly due to the superior treatment's high weed-control efficiency [9]. DSAR-SBM+NTW (*Sesbania* brown manuring in direct-seeded aerobic rice with no tillage wheat without rice residue mulch) tends to show higher plant height and grain yield, which may be due to weed suppression and reduction in soil bulk density and increase in soil porosity [10]. *Sesbania* can sometimes also hinder the growth of rice if proper management is not done during the early stages of the crop creating severe competition between the rice crop and *Sesbania* for space sunlight and nutrient, this statement is in accordance with the finding of [11]. Some of the trials tend to show exactly the opposite result according to the above statement, one of the experiments shows that intercropping of DSR with *Sesbania* as brown manure crop yielded (3.65 t ha^{-1}) at par compared to conventional transplanting (3.69 t ha^{-1}) and significantly higher than the treatment without brown manuring [12]. Dropping of the *Sesbania* leaf at (25 DAS by 2,4-D @ 0.5 kg ha^{-1}) either with pendimethalin @ 1.0 kg ha^{-1} or bispyribac-sodium @ 0.025 kg ha^{-1}or both can reduce weed infestation and increase the yield significantly [13]. Brown manuring with *Sesbania* at 20 kg ha^{-1} with proper irrigation practices like irrigation after the disappearance of ponded water can result in higher grain and straw yield in comparison to weedy check plots and similar results like hand-weeded plots [14]. Grassy weeds are usually the most dominant weed found in the rice field and have the potential to reduce the rice grain yield by 11 kg ha^{-1} [3], Controlling them is a hectic process, some studies show that the use of butachlor @ 1.5 kg ha^{-1} as pre-plant surface application + brown manuring with *Sesbania rostrata* + 2,4-D @ 0.50 kg ha^{-1} can give higher grain yield up to 3.88 t ha^{-1} making it significantly on par with the weed-free condition [15].

Table 1 clearly shows that brown manuring has a clear advantage when comes to providing nutrients and suppressing the growth of undesirable weeds over the conventional or the farmer's practice. Sah and Singh 2023 [17] revealed that 100% NPK + *Sesbania* brown manuring in direct-seeded rice can give significantly higher grain yield in comparison to sole NPK without *Sesbania* brown manuring and can remain on par with transplanted rice with the same treatment. Cultivation of rice with Sesbania followed by application of pendimethalin and 2,4-D can efficiently reduce the total weed population by 65.1% and biomass by 86.7% at 30 (DAS) ultimately increasing the yield [18]. Another experiment shows that brown manuring with *Sesbania* can reduce weed density by 50% [19]. Pooled data from an experiment conducted at Punjab agriculture university also shows that treatment consisting of *Sesbania* brown manuring gave grain and straw yield of 3.38 t ha^{-1} and 8.60 t ha^{-1} which remained par with the conventional method of farming [20]. Brown manuring in DSR with *Sesbania* crop resulted in better control of weeds and higher yield than pre-sowing of *Sesbania* alone and later incorporating into the soil prior to the sowing of DSR [21]. *Sesbania* co-culture with dry -direct-seeded rice succeeded to provide higher effective tillers, grain yield, panicle length and panicle weight which remained on par with other treatments and significantly higher than the weedy check

Table 1. Effect of brown manuring on the yield of direct-seeded rice [16]

Year/Methods used	Grain yield (q/ha)	Straw yield (q/ha)
2014 (IP) Improved technology	31.8	34.0
2014 (FP) Farmer's practices	27.3	28.7
2015 (IP) Improved technology	28.6	31.18
2015 (FP) Farmer's practices	24.7	29.4

IP: Improved technology (Brown manuring); FP: Farmer's practice (Use of chemical fertilizer)

plot [22]. An experiment was carried out during the kharif season with six different treatments including foliar spray of $FeSO_4$ (1%) and $ZnSO_4$ (0.5%) alone with the combination with *Sesbania* brown manuring which resulted in the higher yield characters the treatment which consists 2 foliar spray of $FeSO_4$ and $ZnSO_4$ along with brown manure significantly increased the yield attributes like panicle m^2, grain/panicle and grain and straw yield of rice over all other treatments [23]. A similar kind of experiment was conducted during the kharif season of the year 2013 and 2014 and the pooled data show that number of panicles m^2, length per panicle and no of grains per panicle were significantly influenced by *Sesbania* brown manuring the production efficiency in DSR with brown manuring was high (28.99 kg/h/day) in compare to DSR without the use of *Sesbania brown manuring* (23.99 kg/h/day) ultimately increasing the grain yield and stray yield, despite the sole use of various herbicides like bispyribac sodium @ 25g ha^{-1} + (chlorimuron + metsulfuron) @ 4g ha^{-1} [24]. The growth factors like plant height productive tillers and panicle length were found statistically at par with the conventional planting method, sole plantation of direct seeded rice and double zero tillage when compared to brown manuring [25]. In another experiment conducted at Banaras Hindu University, it was concluded that the plant height, numbers of leaves and the numbers of tillers were higher in weed-free plots. However, it remained par with the bispyribac applied brown manuring which shows the superiority of brown manuring in direct-seeded rice [26]. DSR + *Sesbania* brown manuring can increase the number of panicle m2, grain yield t ha^{-1} and no grain per panicle and can be measured up to 309.42 m^2, 21.98 cm, 90.14 grain/panicle and 4.348 t/ha) respectively [24] that may be due to a reduction in crop weed competition as evidenced by higher weed control efficiency and lower weed index. Pooled data of two years shows that plant height (cm), effective tillers (m2), straw yield (t ha^{-1}) and grain yield (t ha^{-1}) were higher in DSR with a combination of *Sesbania* brown manure with prepared field measuring (11.1, 258.3, 8.46 and 3.41) respectively in comparison to the sole plantation of DSR. Late knockdown of the *Sesbania* crop for brown manuring can better suppress the weed population and give more grain and straw yield which is (6.11 and 9.46 t ha^{-1}) respectively [27] Hence it can be seen that *Sesbania* can be the best possible companion crop to rice for brown manuring which can be beneficial for the DSR. We can also say that brown manuring is a better method of weed control and the best mean to attain optimum yield in comparison to the conventional method of farming and farmer's practice.

3. EFFECT OF BROWN MANURING ON THE PHYSIO-CHEMICAL AND BIOLOGICAL PROPERTIES OF THE SOIL

Brown manuring always appreciatively impacts soil physiochemical properties viz, soil structure, organic carbon, bulk density, etc. Soil health can be defined as the ecological equilibrium and the functionality of soil and its capacity to maintain a well-balanced ecosystem with high biodiversity both over and below the surface and productivity [28]. A trial was conducted with two different treatments for two different years 2014 to 2016 that are crop residue and *Sesbania* brown manuring with DSR where they found that the soil bulk density was less and the soil porosity along with the total soil organic carbon was high in SBM applied plot in comparison to the sole DSR, PuTR and DSR with crop residue [29]. Brown manuring can appreciatively impact the soil's physio-chemical properties: soil structure, organic carbon, bulk density and pH. *Sesbania* brown manuring in rice can significantly increase the soil carbon, drop the soil pH, and increase the soil porosity [12]. 25% of nitrogenous fertilizer by brown manuring in direct-seeded rice can increase the organic carbon content (13.04%) [8]. An experiment conducted for 5 years and all the polled shows that the use of SBM can also enhance the soil organic matter (SOM), soil microbial biomass nitrogen (SMBN) and soil microbial biomass carbon (SMBC) and can significantly reduce the bulk density [30]. It can be concluded that *Sesbania* brown manuring in direct-seeded rice + *Sesbania* brown manuring with zero till wheat without rice residue can decrease the soil bulk density and at the same time can increase the total soil porosity over 48.8% similarly can increase the soil microbial biomass carbon, total soil organic carbon and total soil organic matter as well [31]. In an experiment conducted at BHU (Banaras Hindu University) for two consecutive years in the kharif season of 2016 and 2017 they found that EC and pH were slightly lower in treatment consisting of SBM + residue in zero tilled direct seeded rice over CT-DSR + SBM (Conventionally tilled direct seeded rice and *Sesbania* brown manuring) it shows that a slight integration of previous crop residue can significantly alter the results [32].

Table 2. Effects of different planting methods and *Sesbania* brown manuring on direct-seeded rice [32]

Treatments	pH	EC (dS/m)	Organic carbon (%)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
Zero-tilled-Direct seeded rice (ZT-DSR) + SBM	7.82	0.19	0.432	207.0	17.9	222.8
Zero-tilled-Direct seeded rice (ZT-DSR) + SBM + Residue	7.80	0.18	0.434	208.1	18.8	225.0
Conventional tilled-DSR (CT-DSR) + SBM	7.84	0.21	0.430	204.6	16.9	222.1

SBM- Sesbania brown manuring

The above-given Table 2 shows that the use of *Sesbania* brown manuring can not only increase the soil's organic carbon but at the same time it can also increase the soil's nutrient content. There are some detrimental factors too which come with brown manuring, it is seen that N_2O can be maximum under DSR with brown manuring, it tends to increase the organic matter and the decomposition rate which can result in the emission of GHGs. However, the emission of CH4 is less in DSR in comparison to CT-TPR [33]. Another experiment shows that the total organic carbon increased in treatment DSR + BM – ZTW (Direct seeded rice + brown manuring – zero-tilled wheat) measuring (7.80 Mg ha^{-1}) in comparison to DSR – ZTW (Direct seeded rice – zero-tilled wheat) and PTR – CTW (Puddled transplanted rice – conventionally tilled wheat) measuring (7.46 and 7.67 Mg ha^{-1}) respectively [34]. It concludes that the incorporation of brown manuring with direct seeded rice can significantly change the physiological and chemical properties of the soil.

4. EFFECTS OF BROWN MANURING ON THE WEED DENSITY AND DRY BIOMASS

Conventional weed control always being dominant when we talk about weed control but somehow it hinders the soil health, as it makes the soil toxic making it inhabitable to desired crops in the particular area. Increased attention has been seen towards the development of resource conservation practices and among all the options brown manuring is becoming a new trend [12] Consider brown manuring as a reliable method to control weed is total absolute as DSAR + SBM (Direct seeded aerobic rice + *Sesbania* brown manuring) can reduce the density of broad-leaved weeds, narrow-leaved weeds and sedges by 56%, 41% and 50% respectively. Likewise, it can reduce the dry weight of the above by 75%, 65% and 62% respectively [29] Brown manuring can reduce the broad-leaved weed similarly as compared to the weed-free plot and straw mulch plots making it more proficient it can measure up to 63 g m2 [35]. An experiment conducted under the premises of Chandra Shekhar Azad University of Agriculture and Technology showed that the density of different weed species like *Echinochloa* spp, *Leptochloa chinensis, Commelinaceae benghalensis, Eclipta alba, Cyprus* spp and other weeds under DSR + SBM were significantly less measuring (25.1, 15.5, 20.9, 27.4 and 64.2 plants/m2) respectively as compared to without SBM (38.2, 21.6, 32.3, 39.4 and 91.6 plants/m2) at 30 DAS. similarly, dry weed biomass was (31.1, 18.5, 31.0, 29.5 and 29.7 %) less under SBM in comparison to treatment without SBM [24]. dry weight was significantly reduced may be due to the inhibition of germination of weeds resulting from the inhibition of vital metabolic processes stopping cell division, protein synthesis, etc. Some experiments also showed that the application of sole pendimethalin, hand weeding and spraying of sole bispyribac-Na can reduce the weed biomass over the application of brown manure [36]. *Sesbania* brown manuring proved to be successful in decreasing the total weed density (no m^{-2}) and the total weed dry matter (g m^{-2}) measuring (93.7 and 58.9) respectively, it is due to better suppression of the weed during the early stages of the crop [37] it is also seen that the knockdown date of *Sesbania* also matters in better weed control and suppression over the

Table 3. Effects of Brown manuring on the density of weeds (no/m^{-2}) and weed dry weight (g/m^{-2})

Treatments	Density of weeds (no/m^{-2})	Weed dry weight (g/m^{-2})	References
NT-BM	74	152 (BLWs)	[35]
SBM + pendimethalin *fb* 2,4-D *fb* HW (1000 *fb* 500) 3 *fb* 25 *fb* 40 DAS	82	54.5 (BLWs)	[18]
SBM 25 kg/ha	8	22.2	[41]
Line sowing + Brown manuring	14.33	2.21	[42]
SBM at 35 DAS	20.33	6.11	[43]

SBM: Sesbania Brown manuring, BLWs: Broad-leafed weed

year late knockdown of *Sesbania* at 42 DAS resulted in decreased total weed density (No m^{-2}) and total weed dry biomass (g m^{-2}) measuring (25.25 and 6.62) respectively [25] maybe because the foliar area of *Sesbania* will be more if the growth is more, so late knockdown of the crop is more effective and can better suppress the weed population. A similar experiment shows that knocking down *Sesbania* at 28 DAS can result in decreased weed density (no of weeds m^{-2}) measuring 66.11 in comparison to the other dates of knockdown of the *Sesbania* crop [38]. *Sesbania* brown manure knockdown with 2,4-D at 30 DAS can significantly decrease the weed density (No/m2) and weed dry weight (g/m2) measuring (23.03 and 5.24) respectively in comparison to the sole plantation of DSR and farmer's practices [39] it may be due to the late knocking down of *Sesbania* making it bigger in height and to gain more foliage coverage to suppress the growth of the weeds. Using brown manure in zero-till direct-seeded rice with a combination of zero-till wheat and rice residue can significantly decrease the weed density no/m2 and the dry weight of the weeds (g/m2) measuring (87 and 84) respectively [40], that may be due to the extra mulch provided by the rice residue and the zero tilled wheat which suppressed the weed successfully. It seems that brown manure can successfully suppress the weed if planted in the proper way in and with precise tools and time.

Table 3 shows the positive effect of sesbania brown manuring on the total weed density and the dry weight or total biomass of the weeds.

5. CONCLUSION

The lack of labor for agricultural operations in emerging economies like India is a major issue that has spurred the use of alternative techniques like direct sowing instead of transplanting. Direct-seeded rice has the highest rate of weed emergence when compared to other crop establishment techniques of rice. Therefore, it is essential to develop direct seeding practices for weed management that are both economically feasible for farmers and environmentally friendly. Although direct sowing uses the most herbicides and keeps the weed population below the threshold limit, but it does not protect the environment. Therefore a combination of different strategies for weed management should be used including cultural, biological and conventional methods rather than using only one method of weed control. So the use of brown manure should be the prime focus in direct-seeded rice to control the weed and at the same time provide nutrients to sustain its growth lastly we must diversify different methods like brown manuring itself so that we can come up with new strategies to counter the weed infestation in a more efficient way.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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