**Green Fodder Cultivation in the Upper-Gangetic Plains: Adoption Patterns and Challenges**

**Abstract**

This study investigates the adoption patterns and constraints in the production of green fodder crops, including Berseem, Maize, Oat, and Sorghum, in the Upper Gangetic Plains of India. Data were collected using pre-structured and pre-tested schedules, focusing on the districts of Moradabad, Rampur, and Amroha during the agricultural year 2022-23. A multi-stage stratified purposive-cum-random sampling technique was employed to select 180 respondents from two blocks per district based on the highest green fodder acreage. The economic evaluation utilized various cost concepts to assess profitability, revealing that berseem as the most cost-effective crop due to its lower cultivation costs despite slightly lower yields than other fodder crops. A probit model was applied to analyze adoption behavior, identifying the commercial sale of fodder as a significant factor influencing adoption. Furthermore, constraints faced by farmers were ranked using the Friedman two-way ANOVA rank test, with a lack of awareness about fodder production emerging as the most severe barrier. The findings highlight the economic potential of Berseem and provide valuable insights into the challenges and opportunities for enhancing green fodder adoption in the region.

**Keywords:** Adoption, Costs and Returns, Constraints, Fodder, Friedman.

**INTRODUCTION**

In the rural landscapes of the Upper Gangetic Plain in India, the symbiotic relationship between agriculture, animal husbandry, and human life forms a complex tapestry. These intertwined elements, while economically, culturally, and religiously significant, face a critical challenge, notably in fodder cultivation, a pivotal aspect for optimizing livestock production costs, particularly in the context of milk (Dahiya and Kharb, 2003). The centrality of nutritious and high-yielding fodder becomes evident when considering that 60-70% of milk production expenses are attributed to feed and fodder costs. As the primary protein source in dairy rations, the cultivation of quality fodder emerges as an economic linchpin for profitable livestock farming. Fodder crops, rich in digestible proteins, carbohydrates, fats, and minerals, become indispensable elements for ensuring the health and productivity of livestock, with green fodders serving as particularly rich sources of B-carotene (Pathak and Dagar, 2015; Shashikala *et al.,* 2017).

India, a global leader in milk production, stands at the helm with a staggering total livestock population of 535.82 million (20th Livestock Census–2019). Despite this achievement, the nation grapples with challenges in optimizing animal productivity, primarily linked to a deficit in animal feed and fodder (Vijay *et al.,* 2018; Singh *et al.,* 2023). Fodder supplies, once projected to exceed 60% of the total requirement, now dwindle to around 50%, with further expansion proving unsustainable due to competition with other land uses (Kumar et al., 2012). Livestock, often the primary source of revenue for subsistence farmers, serves as insurance against crop failure, directly influencing the livelihood and food security of nearly a billion people globally (Hurst et al., 2005; Downing et al., 2017). India boasts the world's largest and most diverse livestock population, with approximately 70% of households relying on the livestock and agriculture sector for sustenance (Ghosh *et al.,* 2016).

Uttar Pradesh, a key player in the nation's agricultural landscape, contributes significantly to the rural economy. As the largest producer of food grains in India, the state accounts for about 18% of the country's total food grain production. However, despite these agricultural achievements, challenges persist, including low productivity, malnutrition, and fodder scarcity, impacting the development of livestock (Agricultural Statistics at a Glance, 2021). This study is prompted by the stark imbalance between fodder availability and demand, as projections indicate a widening deficit in green and dry fodder by 2050 (IGFRI Vision, 2050). Despite government initiatives, a lack of comprehensive data hampers effective policy formulation and intervention strategies (Jitendra, 2017).

To address the escalating demand for fodder amidst limited arable land, there is a pressing need to enhance the productivity of cultivated fodder crops and explore the utilization of non-arable land areas for pasture development (Vijay *et al.,* 2018). Keeping above facts, this study aims:

* To estimate the cost and returns of major forage crops in the study area;
* to measure the extent of adoption for green fodder in the study area; and
* to identify the constraints in adoption of green fodder in the study area.

By doing so, it seeks to shed light on these critical issues and offer insights that can inform policies and interventions, enhancing the sustainability and productivity of the livestock sector.

 **Materials and methods**

This investigation of production, extent of adoption and constraints has made extensive use of primary data. The pre-structured and pre-tested schedules have been used to gather the farmers information from the sample size. The population sample was drawn using a multi-stage stratified purposive cum random sampling technique. Moradabad, Rampur and Amroha districts have been selected purposively to represent Upper-Gangetic plains of India.

Firstly, a list of blocks lying under Moradabad, Rampur and Amroha districts of Uttar Pradesh was prepared. Based on the highest acreage in fodder cultivation two blocks from each district were purposively selected from Moradabad viz., Munda Pandey and Chhajlat, from Amroha namely Amroha and Joya. Similarly, bilaspur and Swar having maximum area and production in Rampur were selected. From the list a sample of total 180 respondents were drawn for the investigation.

**Period of Enquiry**

The data pertained to agricultural year 2022-2023to estimate costs and returns of major green Fodder crops viz. Berseem, Maize, Oat and Sorghum.

1. **Measures of Cost Concepts:**

**Cost A1 :** It includes total cash expenses incurred by cultivators which are as follows:

(i) Wage of hired human labour

(ii) Charges for bullock labour

(iii) Hired labour charges of implements and machinery

(iv) Cost incurred on manures and fertilizers

(v) Seeds

(vi) Plant protection chemicals

(vii) Irrigation charges

(viii) Land revenue

(ix) Depreciation, and

(x) Repair charges on farm assets.

Cost A2: Cost A1 + Rent paid for leased in land.

**Cost B1:** Cost A2 + Interest on owned fixed capital assets.

**Cost B2:** Cost B1 + Rental value of owned land.

**Cost C1**: Cost B1 + Imputed value of family labour.

**Cost C2:** Cost B2 + Imputed value of family labour.

**Cost C3:** Cost C2 + 10% of cost C2 (managerial cost)

1. **Measures of Farm Profit:**

**Gross Income** = Value of total output.

**Net Income** = It is computed by deducting cost C3 from gross income.

**Farm Business Income =** Gross Income - Cost A2**or**

 Net Income + imputed value of family labour

**Family labour income =** Gross Income-Cost C

**Benefit-cost ratio =** Cost C / Gross Income

1. **Probit model**

To determine the linear combination of the independent variable, transformed through cumulative distribution function of the standard normal distribution. Probit model was used to know the probability of green fodder adoption.

P(Y=1|X)=ϕ(Xβ) ----------- (I)

Where,

* ϕ represent the CDF of the standard normal distribution.
* **Y:** Binary variable representing the adoption of green fodder (Y=1 if adopted, Y= 0 if not adopted
* **X:** A set of independent variable that may influence the adoption of green fodder (eg.)
* β**:** vector of coefficient associated with each independent variable

The model can be estimated using maximum likelihood estimated (MLE) where the goal is to find the value of β that maximise the likelihood function. The likelihood function is the joint probability of observing the actual adoption outcomes given the independent variable

L(β)= Π [ϕ(Xβ)]^Y\*[1- ϕ(Xβ)]^(1-Y) ----------- (II)

From equation II we get the log-likelihood function

In L(β)=

To identify the value of β that maximizes the log-likelihood function, one must use numerical optimization techniques like the Newton-Raphson method or the Fisher Scoring algorithm as part of the maximum likelihood estimation process.

Once the model is estimated the coefficients can be interpreted to understand the influence of each independent variable on the adoption of green fodder. Where positive coefficient indicates positive relationship while negative coefficient indicates negative relationship. Whereas the magnitude of the coefficient reflects the strength of the relationship

1. **Constraints Analysis:**

The response of the constraints was recorded on a three-point scale of severity, with the order of most severe, severe, and not severe. Plausible constraints were selected based on primary data according to the prepared schedule. A thorough, reconnaissance was conducted in the study locale. The data used Nonparametric test i.e. Friedman two-way ANOVA by rank test, explained by (Tripathi, 2014). Using the following formula the most severe constraints were identified faced by green fodder grower among six broad constraints:

Where,

 N= Number of respondent.

n= Number of constraints

**Results and Discussion**

The major green fodder crop was grown by the farmer were Berseem, Maize, Oats and Sorghum. Hence a comparative analysis of cultivation cost was done for these crop in upper Gangetic plain of India. The input- output coefficient were market out for different crop separately. The details of the cost involved in the cultivation of these crops under various sub head are given in Table 1.

**Table 1 Per hectare costs of different inputs used in Forage production (Rs.)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **S. No.** | **Particulars** | **Berseem** | **Maize** | **Oat** | **Sorghum** |
| **1** | **Human Labour** | 21550.55 | 26121.32 | 25506.80 | 26829.67 |
| a. | Family Labour | 5425.32 | 7533.21 | 6425.23 | 5641.14 |
| b. | Hired Labour | 16125.23 | 18588.11 | 19081.57 | 21188.53 |
| **2** | **Machinery Charges** | 4532.21 | 4754.57 | 6562.11 | 5815.00 |
| **3** | **Seed** | 2656.21 | 2802.22 | 3108.02 | 2403.52 |
| **4** | **Manure and fertilizer** | 4895.22 | 7395.22 | 5326.32 | 6365.11 |
| **5** | **Irrigation** | 3002.32 | 1023.32 | 3243.88 | 2056.32 |
| **6** | **Plant Protection** | 652.74 | 723.15 | 689.66 | 523.31 |
| **7** | **Total operation capital** | 37289.25 | 42819.80 | 44436.79 | 43992.93 |
| **8** | **Interest on working capital** | 1678.02 | 1926.89 | 1999.66 | 1979.68 |
| **9** | **Rental value of land** | 15000.00 | 15000.00 | 15000.00 | 15000.00 |
| **10** | **Interest on fixed capital** | 323.00 | 425.32 | 401.75 | 510.32 |
| **11** | **Sub total** | 54290.27 | 60172.01 | 61838.20 | 61482.93 |
| **12** | **Managerial Cost@10% of sub-total** | 5429.03 | 6017.20 | 6183.82 | 6148.29 |
| **Grand total** | **59719.29** | **66189.21** | **68022.02** | **67631.23** |

**Figure 1** **Per hectare costs of different inputs used in Forage production (%)**

For inputs estimates, the various factors which enters into cost have been
considered such as human labour (both family and hired), machinery charges, seed,
manures & fertilizer, irrigation, plant protection, interest on working capital, rental value of
land, interest on fixed capital and 10% covered managerial cost against C2.

The results showed that cost of cultivation for green fodder crop was minimum on Berseem (Rs. 59719.29) followed by maize (66189.21), Sorghum (67631.23) and oats (68022.02). The analysis lays the foundation for a closer exploration of Berseem's potential as a formidable option in the realm of forage crop cultivation.

Per hectare cost of cultivation of all four fodder crop was highest mainly due to maximum investment in human labour as shown in figure 1 viz., Sorghum (26829.67), maize (26121.32), Oats (25506.80) and Berseem (21550.55). Similarly, family labor expenses for berseem at Rs. 5,425.32 are lower than those for maize (Rs. 7,533.21), Oat (Rs. 6,425.23), and sorghum (Rs. 5,641.14). Hired labor costs also favor Berseem (Rs. 16125.23) over maize (Rs. 18588.11), oat (Rs. 19081.57), and sorghum (Rs. 21188.53). Berseem exhibits cost-effectiveness in machinery charges (Rs. 4,532.21), seed (Rs. 2,656.21), manure and fertilizer (Rs. 4,895.22), irrigation (Rs. 3,002.32), and plant protection (Rs. 652.74) compared to the other crops. The total working capital for berseem is Rs. 37289.25, presenting a cost advantage over Maize (Rs. 42819.80), Oat (Rs. 44436.79), and sorghum (Rs. 43992.93). Interest on working capital and interest on fixed capital for berseem are also relatively lower than those for Maize, Oat, and Sorghum. The subtotal for berseem (Rs. 54290.27) surpasses that of Maize (Rs. 60172.01), Oat (Rs. 61838.20), and sorghum (Rs. 61482.93). Managerial costs at 10% of the subtotal are Rs. 5429.03 for berseem, Rs. 6017.20 for maize, Rs. 6183.82 for Oat, and Rs. 6148.29 for Sorghum

The detailed breakdown underscores berseem's overall cost efficiency across various input categories, making it a potentially more economical choice for forage production.

In assessing the comparative performance of Berseem, Maize, Oat, and Sorghum in forage production, various key financial metrics shed light on their economic viability. Notably table 2, Berseem exhibits a cost advantage across different cost categories. In terms of Cost A1/A2, Berseem requires Rs. 33541.95 per hectare, positioning it favorably against Maize (Rs. 37213.48), Oat (Rs. 40011.22), and Sorghum (Rs. 40331.47). This trend continues across Cost B1, B2, C1, C2, and C3, where Berseem consistently maintains lower production costs compared to the other crops. Despite a marginally higher yield for Sorghum (1615.31 q/ha.) followed by oats (1358.87 q/ha), Maize (1217.00 q/ha.) and berseem (1208 q/ ha). Berseem manages to generate competitive Gross Income (Rs. 108720.00) and Net Returns (Rs. 44402.71). The Input-Output ratios further highlight Berseem's efficiency, with favorable values across all cost bases (A1, B1, B2, C1, C2, C3) when compared to Maize, Oat, and Sorghum. Additionally, Berseem contributes positively to Family Income (Rs. 59855.05) and Farm Business Income (Rs. 75178.05), showcasing its potential as a financially rewarding option for forage production. Overall, Berseem emerges as a cost-effective and economically efficient choice when contrasted with Maize, Oat, and Sorghum in the context of the provided financial data.

**Table 2 Measures of per- hectare cost and profits of Forage (Rs.)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **S. No.** | **Particulars** | **Berseem** | **Maize** | **Oat** | **Sorghum** |
| 1 | Cost A1/A2 | 33541.95 | 37213.48 | 40011.22 | 40331.47 |
| 2 | Cost B1 | 33864.95 | 41818.80 | 45951.46 | 47111.79 |
| 3 | Cost B2 | 48864.95 | 56818.80 | 60951.46 | 62111.79 |
| 4 | Cost C1 | 39290.27 | 49352.01 | 52376.69 | 52752.93 |
| 5 | Cost C2 | 54290.27 | 64352.01 | 67376.69 | 67752.93 |
| 6 | Cost C3 | 64317.29 | 70787.21 | 74114.36 | 74528.23 |
| 7 | Yield q/ha. | 1208.00 | 1217.00 | 1358.87 | 1615.31 |
| 8 | Gross Income | 108720.00 | 133870.00 | 129092.65 | 145377.90 |
| 9 | Net returns  | 44402.71 | 63082.79 | 54978.29 | 70849.67 |
| 10 | Family Income | 59855.05 | 77051.20 | 68141.19 | 83266.11 |
| 11 | Farm Business Income | 75178.05 | 96656.52 | 89081.43 | 105046.43 |
| 12 | Cost of production (q/ha.) | 53.24 | 58.17 | 54.54 | 46.14 |
| 13 | **Input-Output ratio** |
| a. | On the basis of cost A1 | 3.24 | 3.60 | 3.23 | 3.60 |
| b. | On the basis of cost B1 | 3.21 | 3.20 | 2.81 | 3.09 |
| c. | On the basis of cost B2 | 2.22 | 2.36 | 2.12 | 2.34 |
| d. | On the basis of cost C1 | 2.77 | 2.71 | 2.46 | 2.76 |
| e. | On the basis of cost C2 | 2.00 | 2.08 | 1.92 | 2.15 |
| f. | On the basis of cost C3 | 1.69 | 1.89 | 1.74 | 1.95 |

Table 3 presents the results of a probit model used to assess the extent of adoption for green fodder, with various explanatory variables. Fodder availability throughout the year exhibits a positive but statistically non-significant impact (coefficient = 0.324, z = 0.221, p = 0.143), suggesting a marginal effect of 0.3889 on adoption. Similarly, the desire to improve animal health and milk production yields a positive yet non-significant coefficient (0.083, z = 0.227, p = 0.714) with a marginal effect of 0.3000. Notably, selling fodder on a commercial basis emerges as a significant factor influencing adoption, as indicated by its positive and statistically significant coefficient (0.532, z = 0.270, p = 0.049\*), suggesting a marginal effect of 0.2056. Conversely, variables such as the barter system, improving soil health, easy availability of urban markets for marginal and small farmers, lack of pasture land, and the perception of forage cultivation as less risky and cost-effective do not significantly affect the extent of green fodder adoption. The overall fit of the model is evaluated through the log-likelihood (-104.617) and the chi-squared statistic (10.676 with 5 degrees of freedom), providing insights into the goodness of fit and statistical significance of the probit model for assessing adoption behaviors.

**Table 3 Measure the extent of adoption for green fodder**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Explanatory variable** | **Coefficient** | **Z value** | **P** | **[95% Confidence Interval]** | **Marginal Effect** |
| **Fodder availability throughout the year** | 0.324 | 0.221 | 0.143 | -0.109 | 0.758 | 0.3889 |
| **Improve animal health and milk production** | 0.083 | 0.227 | 0.714 | -0.362 | 0.529 | 0.3000 |
| **Selling fodder on commercial basis** | 0.532 | 0.270 | 0.049\* | 0.001 | 1.063 | 0.2056 |
| **Barter System** | -0.113 | 0.300 | 0.706 | -0.703 | 0.476 | 0.1389 |
| **Improving soil health** | -0.273 | 0.215 | 0.205 | -0.696 | 0.149 | 0.4500 |
| **Easy availability of urban market for marginal and small farmers** | 0.167 | 0.221 | 0.452 | -0.268 | 0.601 | 0.3611 |
| **Lack of pasture land** | -0.146 | 0.217 | 0.501 | -0.571 | 0.279 | 0.3667 |
| **Less Risky and cost effective** | -0.310 | 0.235 | 0.187 | -0.772 | 0.151 | 0.2611 |
| **Log Likelihood** | -104.617 |
| **Chi2 (5)** | 10.676 |

**Constraints faced by the fodder farmers**

The data represents (Table 4) different constraints of forage crop production, and the Friedman Test has been used to rank these constraints based on their severity. The ranking is determined by calculating the mean (X̅) and Friedman Mean Score for each constraint. The constraints are then ranked from most severe to least severe based on their Friedman Mean Scores.

 **Lack of awareness about fodder production:** This constraint is ranked as the most severe (I) based on its low mean (X ̅) and high Friedman Mean Score. It indicates that a significant number of respondents consider the lack of awareness about fodder production as a major obstacle to forage crop cultivation.

**Preference for the cultivation of food crops:** This constraint is ranked as the second most severe (II). While it has a slightly higher mean (X ̅) compared to the constraint of lack of awareness, its Friedman Mean Score is slightly lower. This suggests that the preference for cultivating food crops over forage crops is also considered a significant constraint by the respondents.

**Non-availability of labour:** Ranked as the third most severe (III), this constraint has a relatively lower mean (X ̅) and Friedman Mean Score compared to the previous constraints. However, it still represents a significant obstacle to forage crop production according to the respondents.

**Lack of agricultural land:** This constraint is ranked as the fourth most severe (IV). It has a higher mean (X ̅) and Friedman Mean Score compared to the previous constraints, indicating that it is considered a substantial limitation for forage crop cultivation.

**Non-availability of inputs:** Ranked as the fifth most severe (VI), this constraint has a relatively lower mean (X ̅) and Friedman Mean Score compared to the constraints mentioned above. It suggests that the non-availability of inputs is considered a significant constraint, but to a lesser extent than the previously mentioned constraints.

**Unavailability of High Yielding Variety developed by IGFRI:** This constraint is ranked as the least severe (V). It has the lowest mean (X ̅) and Friedman Mean Score among the listed constraints, indicating that it is perceived as the least significant limitation for forage crop production.

 Overall, the constraints are ranked based on their severity, with "lack of awareness about fodder production" being the most severe constraint, followed by "preference for the cultivation of food crops," "non-availability of labour," "lack of agricultural land," "non-availability of inputs," and "unavailability of High Yielding Variety developed by IGFRI" being the least severe constraint.

**Table 4. Responses of the constraints faced by the fodder farmer**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Constraints** | **Most severe** | **severe** | **Least severe** | **Mean ()** | **Friedman Mean Score** | **Overall Rank** |
| **Non-availability of inputs** | 106 (58.90) | 42 (23.30) | 32 (17.80) | 0.58 | 3.26 | VI |
| **Lack of agricultural land** | 100 (55.60) | 43 (23.90) | 37 (20.60) | 0.65 | 3.41 | IV |
| **Lack of awareness about fodder production** | 81 (45.00) | 54 (30.00) | 45 (25.00) | 0.80 | 3.73 | I |
| **Preference for the cultivation of food crops** | 80 (44.40) | 62 (34.40) | 38 (21.10) | 0.76 | 3.66 | II |
| **Non-availability of labour** | 90 (50.00) | 46 (25.60) | 44 (24.40) | 0.74 | 3.55 | III |
| **Unavailability of High Yielding Variety developed by IGFRI**  | 98 (54.40) | 47 (26.10) | 35 (19.40) | 0.65 | 3.39 | V |

**Table 5 Test Statistics of Friedman test**

|  |  |
| --- | --- |
| **Test Statistics** | **Value** |
| **N** | 180 |
| **Chi-Square** | 10.77 |
| **df** | 5 |
| **Asymp. Sig** | 0.000 |
| **Monte Carlo Sig.** | **Sig.** | 0.000 |
| **99% Confidence Interval** | **Lower Bound** | 0.000 |
|  | **Upper Bound** | 0.000 |

**CONCLUSION**

The above discussion unfolded that berseem emerged as the most economically viable fodder crop, with lower production costs and higher returns compared to Maize, Oat, and Sorghum. The Probit model analysis confirmed that the commercial sale of fodder plays a crucial role in driving the adoption of green fodder crops, underscoring the economic incentives for farmers to diversify into fodder production. However, significant constraints, particularly the lack of awareness about fodder cultivation practices, continue to impede broader adoption. Addressing these challenges through targeted extension services, training programs, and the promotion of fodder-related market linkages can significantly enhance farm income and contribute to sustainable livestock farming. The study emphasizes the need for concerted efforts by policymakers, extension agents, and agricultural stakeholders to improve access to knowledge and resources, ensuring that green fodder cultivation becomes a viable and widely adopted agricultural practice in the region.

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**1. Quillbot**

**2. Chat GPT**

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