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Effect of farmyard manure, nitrogen and phosphorus on productivity, growth, water use efficiency and economics of tomato production in Hamelmalo, Eritrea

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Abstract

In Eritrea the average yield of tomato is meager as farmers usually use inadequate and inappropriate proportions of nutrient inputs; therefore, to develop a better understanding of nutrient management, a field experiment was conducted at the research area of Hamelmalo Agricultural College, Eritrea with the objective to determine the effect of farmyard manure (FYM) and chemical fertilizers on growth, yield, water use efficiency and economics of tomato production. The experiment was laid down in a split plot design with FYM as the main plot; nitrogen (N) and phosphorus (P) combination levels in subplots with three replications. The FYM treatments were 0 and 10 t ha-1. N and P combination treatments were 0%, 75%, 100%, 125% and 150% of the recommended N and P dose. The recommended dose of N and P2O5 locally used was 120 kg and 80 kg ha-1, respectively. All the data collected were analyzed using Gen-stat software. The results showed that 10 t FYM ha-1 + 150 kg N and 100 kg P2O5 ha-1 had a significant effect on tomato yield, followed by 150 kg N and 100 kg P2O5 ha-1 alone. The water use efficiency of tomatoes was also significantly affected by the application of both FYM and inorganic fertilizers (N and P). The highest water use efficiency of tomato was recorded with the application of 10 t ha-1 FYM + 150 kg N and 100 kg P2O5 ha-1. Gross margin per nakfa analysis showed that applying 10 t FYM ha-1 along with 150 kg N and 100 kg P2O5 ha-1, was more economical.

Key words: FYM, nitrogen, phosphorus, water use efficiency, economics, yield, tomato.

Introduction

In Eritrea, tomato (Lycopersicon esculentum Mill.) is grown almost all over the country, mostly under irrigation (furrow, drip or spate irrigation) and sometimes under rain fed conditions. It is the most widely used vegetable as sauce, soup and salad, making the staple food more palatable. Tomato production has a long tradition among Eritrean farmers because of its high demand and reasonably good yield and return (Asgedom et al., 2011). However, the average yield of tomato still remains very low which is around 10 t ha^{-1} (MoA, 2015) compared even to the neighboring country, Kenya (23.2 t ha^{-1}), (FAO, 2013). Eritrean farmers normally use inadequate nutrient inputs, inappropriate proportions and inefficient combinations of fertilizers, which in turn increase the cost of inputs (MoA 2015). Productivity in Eritrea has been far below than in other developing country with similar agro-climatic conditions, mainly due to low nutrient status of soils (Negassi et al., 2002). Therefore, a better understanding of the nutrient requirement for tomato production is required in order to develop management strategies, which optimize fertilizer use by the crop thereby increasing returns to the farmers through increased yield. Thus, the present investigation was undertaken to study the effect of farmyard manure (FYM), nitrogen (N) and phosphorus (P) on yield, water use efficiency and economics of tomato production.

Materials and Methods

Site description

The field experiment was conducted under irrigation conditions in Hamelmalo Agricultural College (HAC), located at 150 52'18'' N and 380 27'55'' E, and an elevation of 1280 m above sea level in semi-arid agro-ecological region of Eritrea; annual average rainfall in the growing season was 436.3 mm, the maximum and minimum temperature of the research area were 34.7 0C and 11.1 0C, respectively (Meteorological observatory, HAC). Soil physico-chemical properties of the experimental field were determined before sowing using standard methods and procedures. The results of the phisico-chemical properties of composite sample of the area are presented in Table 1.

Table 1: The physico-chemical properties of the soil before sowing

Soil parameters	Value
Sand (%)	59.8
Silt (%)	26.6
Clay (%)	13.6
Textural class	Sandy loam
Bulk density (g cm^{-3})	1.65
Field capacity (%) by weight	11.6
EC (1:5) (dSm^{-1})	0.08
pH (1:5)	8.2
Organic matter (%)	0.49
Available nitrogen (%)	0.008
Extractable phosphorous (ppm)	2.7
Exchangeable potassium ($cmolkg^{-1}$)	0.89
Exchangeable Ca ($cmolkg^{-1}$)	26.5
Exchangeable Mg ($cmolkg^{-1}$)	4.65
Exchangeable Na^+($cmolkg^{-1}$)	0.18
CEC ($cmolkg^{-1}$)	28.6

Experimental design

A split-plot design was used with 10 treatments and three replications. The plot size was 3.0 m x 2.0 m and the spacing between row to row and plant to plant was 75 cm and 40 cm, respectively. The space between plots and blocks was 1.0 m and 1.5 m, respectively. Each plot was prepared with four rows of furrows and ridges. The ridges were 30 cm high and the length of the furrows and spacing between them were 2.0 m and 0.75 m, respectively. Two farmyard manure (FYM) levels as the main plot and five levels of nitrogen (N) and phosphorus (P) fertilizers combinations as the sub-plot were taken. The Riogrande variety of tomato was sown in the nursery on a flat seed bed one month before transplanting at a seed rate of 200 g per 250 m^2 of seedbed, with a spacing of 10 cm between rows. Weeding and irrigation practices were applied as and when required. Seedlings were transplanted 30 days after being sown in the nursery. The plants were spaced row to row 0.75 m apart and plant to plant 0.40 m apart, for a total of 20 plants per plot. Gap filling was done within 10 days after transplanting to replace the dead and weak plants. The plots were kept free of weeds by regular hand weeding and intercropping management practices. Fulldazim Wp 50% (a fungicide) was applied three times whenever the symptoms of collar rot (a fungal disease) were observed. Dimethox (an insecticide) was also applied twice to control pests. Pests like late blight, tuta absoluta and boll worm were observed during the crop season. The decomposed FYM was applied and incorporated into the soil two weeks before transplanting. All P and 26% of the total N fertilizer dose were added during transplanting. The other half of N fertilizer was applied in two split doses: one at 30 days after transplanting and the second at the stage of fruit setting. Irrigation scheduling was done at 50% soil moisture depletion.

Treatments

Farmyard manure (FYM): FYM0 = 0 t ha^{-1} and FYM1= 10 t ha^{-1}

NP fertilizer levels: T0 = 0% of the recommended N- P_2O_5 (0-0 Kg ha^{-1});

T1 = 75% of the recommended N- P_2O_5 (90-60 Kg ha^{-1});

T2 = 100% of the recommended N- P2O5 (120-80 Kg ha^{-1});

T3 = 125% of the recommended N- P_2O_5 (150–100 Kg ha^{-1});

T4 = 150% of the recommended N- P_2O_5 (180-120 Kg ha-1)

The recommended doses of nitrogen and phosphorus were 120 N kg ha^{-1} and 80 P_2O_5 Kg ha^{-1} (Asgedom et al., 2011).

The number of days to flowering of tomatoes was recorded as the number of days from transplanting to the time when 50% of the plants in each plot developed flowers. Cumulative numbers of fruits per plant at successive pickings were counted from four randomly selected plants in the net pot in each treatment and their average number was calculated. The weight of the fruits per plant was calculated by adding the weight of harvested fruits from four randomly selected plants at every picking within the net plot and their average weight was calculated and expressed as fruit weight per plant in kg. The cumulative total fruit harvested from successive pickings, including the non-marketable ones, was weighed per net plot and expressed in t ha^{-1}. From the total fruits harvested, all healthy fresh fruits free from cracks, insect damage and small-sized fruits were separated to calculate the marketable yield and expressed in t ha^{-1}. The rotten, insect-damaged, small sized and cracked fruits that could not be sold were weighed and expressed in proportion to the total harvested fruit yield.

Water use efficiency was calculated as marketable fresh fruit weight (kg ha^{-1}) obtained per unit volume of irrigation water applied (m^3 ha^{-1}) (Zotarelli et al., 2009).

The partial economic analysis was done using the partial budget procedure to determine the treatment that would give an acceptable return at low risk to the farmer (CIMMYT, 1988). The economic analysis of the data was done based on the prevailing farm gate prices of inputs, operations and outputs. The following concepts used in the partial budget analysis are defined as follows:

(The economic analysis was done using the partial budget procedure to determine the treatment that would give an acceptable return at low risk to the farmers (CIMMYT, 1988). The economic analysis of the data was done based on the prevailing farm gate prices of inputs, operations and outputs. The following concepts used in the partial budget analysis are defined under:)

Gross Revenue (GR) in Nakfa (local currency) ha^{-1} is the product of the average price of tomatoes and the total marketable yield for each treatment.

Total variable cost (TVC) in Nakfa ha^{-1} is the cost of labour and inputs, which include seeds, fertilizers and chemicals.

Gross margin (GM) in Nakfa ha^{-1} is the difference between gross revenue and total variable costs.

Gross margin per Nakfa invested is the gross margin divided by total variable cost (TVC).

Results and Discussion

Yield Parameters

The weight of fruits and total yield were significantly increased due to the application of FYM (Table 2). There was an increase in weight of fruits and total yield due to the application of FYM of 10.5% and 16.6%, respectively, over control. This could be due to FYM's ability to conserve soil moisture and supply nutrients. These results were in agreement with the observations of Bairagya et al. (2019), who reported that the combined application of FYM and vermicompost increased the total yield of tomatoes. Days to 50% flowering, number of fruits per plant, weight of fruits per plant, marketable yield, non-marketable yield and total yield of tomatoes were significantly affected by the application of N and P fertilizers (Table 2). Plants with treatments of 180 kg N and 120 kg P_2O_5 ha^{-1} produced the highest marketable yield (36.44 t ha^{-1}) and total yield (37.86 t ha^{-1}). In all the treatments, the control plot recorded the highest number of days to 50% flowering, the least number of fruits per plant, the weight of fruits per plant, marketable yield, non-marketable yield and total yield with values of 44.33, 17.41, 0.34 kg, 11.94 t ha^{-1}, 0.237 t ha^{-1} and 12.18 t ha^{-1}, respectively. The treatments that recorded the highest mean values could be due to the availability of N and P, which enabled the plant to have rapid vegetative growth and the development of reproductive parts, enhancing fruit development. These results were in agreement with the findings of Sigaye et al. (2022), reporting highly significant ($P < 0.01$) interaction effects of nitrogen and phosphorus fertilizer application during all growing seasons on total and marketable fruit yields of tomatoes.

The number of fruits and marketable yield were significantly affected due to the combined application of FYM and N-P combination levels (Table 2). However, there was no significant difference in days to 50% flowering, weight of fruits per plant, non-marketable yield or total yield of tomatoes among the combined use of FYM and inorganic fertilizers (N and P); however, the highest weight of fruits per plant (1.21 kg) and total yield (40.5 t ha^{-1}) were recorded with treatments 10t ha^{-1} FYM + 180 kg N and 120 kg P_2O_5 ha^{-1} and 10 t ha^{-1} FYM + 150 kg N and 100 kg P_2O_5

ha^{-1}, respectively. This could be explained on the basis of the ability of FYM to conserve moisture and the availability of nutrients in the soil due to the application of N and P fertilizers. Geremew et al. (2019) and Mohit et al. (2019) also reported similar results.

Table 2: Effect of FYM, N and P on days to 50% flowering, number of fruits per plant, weight of fruits per plant, marketable fruits, non-marketable fruits, total yield and water use efficiency of tomatoes

Treatment	Days to 50% flowering	Number of fruits per plant	Weight of fruits/ plant (kg)	Marketable fruit (t/ha)	Non marketable fruit (t/ha)	Total yield (t/ha)	Water use efficiency (kg/mm)
FYM0	41.27	24.65	0.76	23.69	1.091	24.79	34.85
FYM1	40.27	25.03	0.84	27.86	1.049	28.91	40.97
LSD (5%)	NS	NS	47.66*	NS	NS	1.589*	1.833*
CV (%)	5.5	4.9	4.3	1.4	11.3	1.7	1.4
T1	44.33	17.41	0.34	11.94	0.237	12.18	17.56
T2	44	23.76	0.66	21.65	0.902	22.55	31.84
T3	39	26.78	0.84	26.96	1.265	28.23	39.65
T4	41.17	30.07	1.03	36.44	1.423	37.86	53.58
T5	39.33	26.19	1.15	31.9	1.523	33.43	46.92
LSD (5%)	3.248*	3.107**	0.046**	0.717**	0.1446**	0.1446**	1.054**
FYM_0+T_1	46	14.66	0.31	10.2	0.247	10.45	15
FYM_0+T_2	41	24.72	0.62	19.87	0.92	20.79	29.23
FYM_0+T_3	39.33	24.55	0.8	25.18	1.27	26.45	37.03
FYM_0+T_4	41	31.05	0.98	33.72	1.493	35.22	49.59
FYM_0+T_5	39	28.27	1.1	29.49	1.527	31.02	43.37
FYM_1+T_1	42.67	20.16	0.37	13.68	0.227	13.91	20.12
FYM_1+T_2	39	22.79	0.7	23.43	0.883	24.31	34.45
FYM_1+T_3	38.67	28.99	0.87	28.74	1.26	30	42.26
FYM_1+T_4	41.33	29.1	1.07	39.15	1.353	40.5	57.57
FYM_1+T_5	39.67	24.12	1.21	34.31	1.52	35.83	50.46
LSD (5%)	NS	4.761*	NS	1.119*	NS	NS	1.645*
CV (%)	6.5	10.2	4.6	2.3	11	11	2.3
Grand mean		24.84	0.8	25.78	1.07	26.85	37.91

FYM = farmyard manure FYM_0 = 0 t ha-1, FYM_1 = 10 t ha$^{-1.}$
LSD (5%) = least significant difference at 5% CV = coefficient of variation
T_1 = N-P_2O_5 (0-0) kg ha^{-1} T_2 = N-P_2O_5 (90-60) kg ha^{-1} T_3 = N-P_2O_5 (120-80) kg ha^{-1}
T4 = N-P_2O_5 (150-100) kg ha^{-1} T_5 = N-P_2O_5 (180-120) kg ha^{-1} N = Nitrogen P = phosphorus; * = statistically significant; ** = statistically highly significant. NS = non-significant

Water use efficiency (WUE) of tomatoes

A perusal of the data in Table 2 revealed that the application of FYM had a significant effect on WUE. There was an increase of 17.6% in WUE due to the application of FYM. Similarly, application of FYM combined with N-P combination levels showed a significant change in the WUE of tomatoes. The highest mean value (57.57 kg mm^{-1}) was recorded with 10 t FYM ha^{-1} + 150 kg N and 100 kg P_2O_5 ha^{-1} and the lowest (15 kg mm^{-1}) in control (no inputs) with an average of 37.91 kg mm^{-1}. This could be due to the optimum availability of N and P and the improvement of soil physical conditions to conserve soil moisture. This observation justified the fact that WUE increased with an increase in yield due to the application of FYM, N and P fertilizers (Havlin et al., 2005). The application of N-P combination levels showed a highly significant difference in WUE. The highest mean value (53.58 kg mm^{-1}) was recorded with 180 kg N and 120 kg P_2O_5 ha^{-1} and the lowest value (17.56 kg mm^{-1}) in control.

Partial Economic Analysis

Results of the economic analysis (Table 3) showed that the highest gross margin (Nakfa) was obtained from treatment with 10 t ha^{-1} FYM + 150 kg N and 100 kg P_2O_5 ha-1, followed by 150 kg N and 100 kg P_2O_5 ha^{-1} application alone and the lowest was recorded in control (no inputs). From these results, it could be generalized that treatments with a high dose of the N and P combination level and the application of 10 t ha^{-1} FYM seemed to increase the total cost of production, whereas those with a lower dose and without FYM showed a lower cost of production. Other costs of production were equal for all treatments. The gross margin per one Nakfa ranked highest with 10 t ha^{-1} FYM + 180 kg N and 120 kg P_2O_5 application (3.135), followed by 180 kg N and 120 kg P_2O_5 application alone (2.936) and the lowest was in control (1.01), which were 243.6% and 220.7% higher, respectively, over the control. Thus, the interactive effect was more profitable than their individual effect under the conditions of the experiment. Heeralal et al. (2023) also reported that the application of integrated nutrient management significantly affected the growth, yield parameters and economics of tomato production.

Conclusion

The present investigation indicated some distinct benefits of combined use of organic and inorganic sources of fertilizers than one source alone. The results of this study showed that 10 t FYM ha^{-1} + 150 kg N and 100 kg P_2O_5 ha^{-1} application was most appropriate and economical for better yield of tomato under irrigation in Hamelmalo; this also supported the integrated nutrient management for tomato production. In addition the study revealed that application of FYM combined with N-P combination levels showed significant increase in WUE of tomato. The highest WUE (57.57 Kg mm^{-1}) was recorded in 10 t FYM ha^{-1}+ N-P_2O_5 (150-100) Kg ha^{-1}) application. Gross margin per Nakfa also increased with combined use of inorganic and organic fertilizers.

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Table 3: Partial economic analysis of tomato yields due to application of farmyard manure, nitrogen, and phosphorus

Treatment	Total variable Cost (Nakfa) ha^{-1}	Gross Revenue (Nakfa) ha^{-1}	Gross margin (Nakfa) ha^{-1}	Gross margin (Nakfa) per Nakfa
FYM0	200000	592367	394472	1.897
FYM1	210000	696572	487678	2.251
T1	130000	298597	166164	1.245
T2	190000	541278	350002	1.825
T3	210000	674014	462791	2.188
T4	23000	910903	679732	2.936
T5	250000	797556	546687	2.175
FYM_0+T_1	130000	255083	128150	1.010
FYM_0+T_2	190000	496861	311085	1.675
FYM_0+T_3	210000	629528	423804	2.060
FYM_0+T_4	230000	843083	617413	2.736
FYM_0+T_5	250000	737278	491909	2.005
FYM_1+T_1	140000	342111	204178	1.480
FYM_1+T_2	200000	585694	388919	1.976
FYM_1+T_3	220000	718500	501777	2.135
FYM_1+T_4	240000	978722	742051	3.135
FYM_1+T_5	260000	857833	601465	2.346

FYM = Farmyard manure; FYM_0 = 0 t ha^{-1} FYM_1 = 10 t ha^{-1}; LSD (5%) = Least significant difference at 5%; CV = Coefficient of Variation; T_1 = N- P_2O_5 (0-0) kg ha^{-1}; T_2 = N- P_2O_5 (90-60) kg ha^{-1}; T_3 = N- P_2O_5 (120-80) kg ha^{-1}; T_4 = N- P_2O_5 (150-100) kg ha^{-1}; T_5 = N- P_2O_5 (180-120) kg ha^{-1}

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Evaluation of different strains of oyster mushrooms for yield performance

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Abstract

Oyster mushrooms have palatable, beneficial and pharmaceutical values and can grow on byproducts used as a substrate, which are considered waste obtained from agriculture, households, and industries. These can effortlessly degenerate agricultural residues, can be cultivated in a varied temperature range, require less time to grow and are not frequently attacked by various pathogens and pests. A research study was conducted to evaluate six strains of Pleurotus species (PL-1, PL-2, PL-3, PL-4, PL-5 and PL-6) for yield performance using wheat straw as substrate. The highest yield was produced by PL-3 (414.4 g/bag), followed by PL-2 (399.8 g/bag) and PL-5 (379.2 g/bag), whereas the lowest yield was found in the PL-4 (192.6 g/bag) strain. The maximum biological efficiency was recorded in PL-3 (69.07 per cent) followed by PL-2 (66.62 per cent) and PL-5 (63.2 per cent) strains. Hence, it can be concluded that oyster mushrooms hold the potential for the valorization of agro-industrial waste among urban and rural communities, not only minimizing environmental impact but also fostering economic development and self-sufficiency.

Keywords: Biological efficiency, Oyster mushroom, Strains, Wheat straw, Yield performance.

Introduction

Mushrooms are macrofungi with distinguishable spore-producing fruiting structures. These distinctive macrofungi congregate their nutrients through the release of enzymes capable of degrading complex organic compounds. On degradation, the fungus grows on its substrate to produce simple nutritional compounds (Chang and Miles 1992). Mushrooms grow on byproducts used as substrate, which are considered waste obtained from agriculture, household and industries. The cultivation of mushrooms represents an economic biotechnological process to convert agricultural and forest leftovers (Wood and Smith 1987). It is an environmentally favourable technology in which the mycelium of these macrofungi releases extracellular enzymes capable of degrading and assimilating lignocellulose material, thus reducing pollution.

Among the various mushroom species cultivated globally, Pleurotus species, commonly referred to as oyster mushrooms, are extensively grown. They rank second in popularity for cultivation, following Agaricus bisporus, commonly known as the button mushroom (Sánchez, 2010; Kües and Liu, 2000). Different species of oyster mushrooms are popular and grown around the globe, mainly in Europe, America, Asia, for their easy, economic production technology and great biological efficiency (Mane *et al*., 2007).

Besides Pleurotus *species* have gained excessive interest because of their palatable, beneficial and pharmaceutical values (Garcha *et al*., 1993). Oyster mushrooms can effortlessly degenerate agricultural residues and can be cultivated at a varied temperature range (Sánchez, 2010). If compared to other edible mushrooms, oysters require less time to grow and are not frequently attacked by various pathogens and pests (Tesfaw *et al*., 2015; Baysal *et al*., 2003). Nitrogen, carbon and inorganic compounds are essential nutrients for *Pleurotus species.* These can be cultivated on various substrates. Oyster mushrooms are a storehouse of proteins, minerals like potassium, calcium, iron, phosphorus, sodium and vitamins like niacin, riboflavin, folic acid, thiamine (Szabová *et al*., 2013). In spite of all these properties, *Pleurotus species* have pharmaceutics value for lowering blood sugar (Nayak *et al*., 2021) and cancer therapy (Sivrikaya *et al.*, 2002; Nayak et al., 2022).

A huge amount of left-over agricultural waste composed of lignocellulose is available in equatorial and semitropical regions. Such agricultural residues are commonly left to decay in the field or burned (Szabová *et al*., 2013). Utilizing locally obtainable substrate to grow *Pleurotus species* is helpful to convert agricultural residues into consumable biomass of commercial and nutritional value (Tesfaw *et al*., 2015). The objective of this study was to identify high-yielding strains of oyster mushrooms, focusing on various yield parameters such as fruit body per bag, average weight of the fruit body and biological efficiency using wheat straw as substrate.

Materials and methods

Study area and experimental materials

The study was conducted at the Mushroom Research and Training Centre (MRTC) of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. In the present investigation, a comparative cultivation of a strain of oyster mushroom was performed. Six strains of oyster mushrooms, namely PL-1, PL-2, PL-3, PL-4, PL-5 and PL-6, were taken and cultivated on wheat straw for their yield performance.

Preparation of spawn

Spawn was prepared from six different strains of *Pleurotus* (PL-1, PL-2, PL-3, PL-4, PL-5 and PL-6) using wheat grains, following the protocol standardized by Garcha (1993). Wholesome, unbroken grains of wheat were used. The wheat grains were first cleansed with water, followed by boiling (grain:water, 1:25, w/v) and tenderized without the seed coat being ruptured. An excess amount of water was rinsed off and dried on a sieve overnight. Thereafter, commercial-grade calcium carbonate and gypsum were added to the boiled wheat grains in the proportion of 4:1 (w/w), i.e., 15 gram per kilogram of wheat grains. The cleaned glass bottles were then filled with wheat grains and corked with nonabsorbent cotton. At 22 lbs of steam pressure (126˚C) the bottles were sterilized for 90 minutes. After sterilization, the glass bottles were removed from the autoclave and in order to avoid clumping, the bottles were shaken.

Afterwards, the grain-filled bottles were inoculated with a portion of the 7–10-day-old pure culture of the particular strain. The glass bottles inoculated with pure culture were incubated for 10 days at 25±1˚C. The inoculated bottles were occasionally shaken, resulting in the separation of threads of mycelium, got blended well with the wheat grains and were kept under observation to check the mycelium run. Thereafter, the grains, when covered by mycelium, were used as spawn.

Substrate preparation and spawning

The wheat straws were taken and sun-dried, followed by the chopping of the straw into 4 cm lengths. The chopped straw was immersed in water and soaked overnight prior to preparing the substrate. An excess amount of water was drained and laid down on the floor, sterilized with ethanol and allowed to sun dry until there was 70% moisture content in the substrate, which was checked with the hand fist. Finally, the substrate was used for the cultivation of oyster mushrooms.

The spawning was done at 3% of ready substrate and the spawned substrate was filled into the polybag at 2 kg per bag. Five replications of each strain were maintained with six bags per replication, respectively.

Cropping and cultivation

For the cultivation of oyster mushrooms, bags inoculated with each strain were placed in a dark room, as suggested by Chang and Miles (2004), to initiate the growth of the mycelium. The bags were observed regularly and on generous growth of mycelium in the bags, the polythene bags were cut off with a sterilized blade or cutter. On removal of the polythene bags, the pin heads started to appear. Soon the bags were moved to the cropping room, where the bags inoculated with a specific strain of *Pleurotus species* were placed on the racks. The spacing maintained between each bag was 15–20 cm. Adequate ventilation was maintained in the cropping room by the occasional opening of the door every two to three days. Moisture in the inoculated bags was assured by spraying water twice a day in order to keep the colonized bags moist. The temperature of the crop room and relative humidity were checked and maintained with a thermohygrometer, with the occasional spray of water in the range of 70–75%.

Collection of data

Regular monitoring on a daily basis of inoculated bags was done for the growth and development of oyster mushrooms. Data were recorded with respect to the number of fruiting bodies, yield, average weight per fruit body, and morphological parameters of the strains. Parameters of growth like pileus diameter (cm), stipe diameter (cm), stipe length (cm) and colour were documented (Table 1). At the time of harvesting, yield parameters like the number of fruiting bodies and the weight of oyster mushrooms were recorded. Mushrooms were harvested by severing the mushroom stalk above the surface of the bag. For evaluating the yield performance of each strain, biological efficiency and yield were calculated (Table 2).

$$\textbf{Biological efficiency (\%)} = \frac{\text{Weight of fresh mushrooms harvested per bag}}{\text{Weight of dry substrate per bag}} \times 100$$

Strain	Stipe Length (cm)	Stipe Diameter (cm)	Pileus Diameter (cm)
PL-1	1.79	0.61	6.7
PL-2	2.48	0.85	7.96
PL-3	1.77	0.86	6.45
PL-4	1.67	0.57	5.96
PL-5	2.48	0.75	6.49
PL-6	1.65	0.76	6.97
CD 5%	0.18	0.17	0.22
CV	0.50	1.29	0.57

Table 1: Morphological variation of different strains of oyster mushroom

Results

Six different strains of *Pleurotus species* (Fig. 1) with reference to production were compared. The strains used exhibited varied performance in harvest and morphological characteristics.

Morphological variation of different strains of oyster mushrooms

On analyzing the strains of *Pleurotus species* (PL-1, PL-2, PL-3, PL-4, PL-5 and PL-6), it was found that strains PL-2 and PL-5 were recorded with the highest stipe length (2.48 cm), followed by PL-1 (1.79 cm), PL-3 (1.77 cm), PL-4 (1.67 cm) and PL-6 (1.65 cm), respectively. Strain PL-3 (0.86 cm) was recorded with the highest stipe diameter, followed by PL-2 (0.85 cm), PL-6 (0.76 cm), PL-5 (0.75 cm), PL-1 (0.61 cm), and PL-4 (0.57 cm). Maximum pileus diameter was recorded for strain PL-2, followed by strains PL-6, PL-1, PL-5, PL-3 and PL-4, respectively (Table 1). In terms of yield, there is a positive correlation between the size of the pileus and the overall yield.

Yield performance of different strains of oyster mushrooms

In terms of number of fruit bodies, strain PL-3 produced the maximum number of 83 fruit bodies, followed by PL-5 and PL-6; however, strain PL-2 produced the least number of 59 fruit bodies (Table 2). The highest yield was produced by PL-3 (414.4 g/bag), followed by PL-2 (399.8 g/bag) and PL-5 (379.2 g/bag), whereas the lowest yield was found in the PL-4 (192.6 g/bag) strain (Table 2). The biological efficiency was highest for strain PL-3 (69.07%) and lowest for strain PL-4 (32.1%).

Discussion

In terms of number of fruit bodies, strain PL-3 produced a maximum of 83 fruit bodies, followed by PL-5 and PL-6; however, strain PL-2 resulted in a minimum of 59 fruit bodies. The fruiting body of the mushroom is the commercially valuable edible part. Among the four cultivation steps in mushroom production, maintaining the spawn bags for fruiting body production is relatively manageable for poor farmers or rural individuals. Kitamoto et al. (1995) reported that the presence of glucose, fructose, and trehalose in the substrate could contribute to an increased number of effective fruiting bodies.

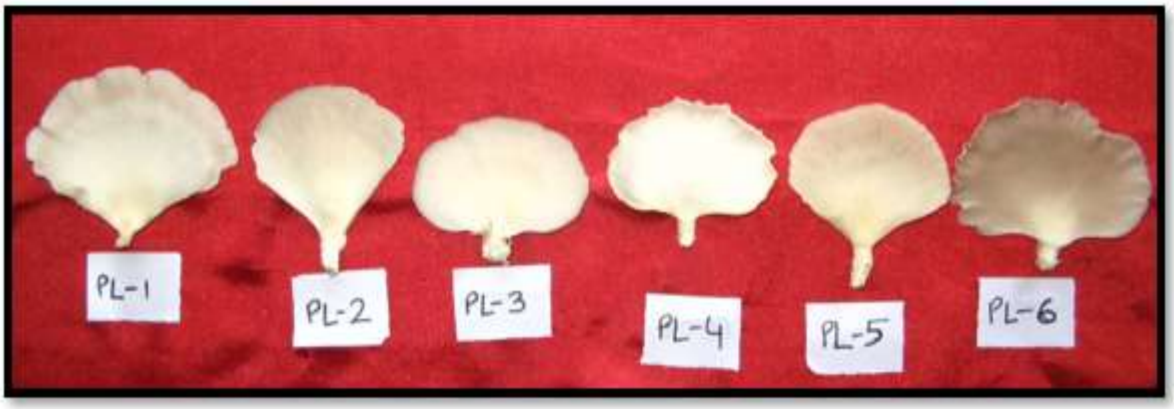

Fig. 1: Six different strains of *Pleurotus species*

Table 2: Yield performance of different strains of oyster mushrooms

Strain	Fruiting body per bag		Avg. wt./fruit body (g)	Biological Efficiency (%)
	No.	Wt.		
PL-1	62.56	325.40	5.20	54.23
PL-2	59.00	399.80	6.78	66.63
PL 3	83.04	414.40	4.99	69.07
PL-4	40.48	192.60	4.76	32.10
PL-5	78.56	379.20	4.83	63.20
PL-6	69.80	318.40	4.56	53.07
CD 5%	15.68	63.44	--	--
CV	18.12	14.21	--	--

The continuous cultivation of oyster mushrooms over the years has resulted in a decline in productivity. Hence, the selection of new strains becomes essential to achieve higher yields and meet the demands of consumers, particularly for underprivileged farmers lacking sterilization and incubation facilities. The rate of sporophore formation by each strain plays a crucial role in oyster mushroom production. In this experiment, significant differences were observed in sporophore production among all the strains utilized. The highest yield was produced by PL3 (414.4 g/bag), followed by PL-2 (399.8 g/bag) and PL-5 (379.2 g/bag), whereas the lowest yield was found in the PL-4 (192.6 g/bag) strain (Table 2).

Biological efficiency is a very good standard parameter to determine the efficiency of substrate conversion in fruiting bodies. The maximum biological efficiency was recorded in PL-3 (69.07 per cent) followed by PL-2 (66.62 per cent) and PL-5 (63.2 per cent) strains. The lowest biological efficiency was found in the PL-4 (32.1 percent) strain. The highest weight per fruit body was recorded at 6.78 g in PL-2, followed by PL-1 and PL-3, but the lowest weight was 4.56g per fruit body in the PL-6 strain (Table 2).

The maximum 2.48-cm stipe length was recorded in PL-2 and PL-5, followed by PL-1. The stipe diameter of all strains ranged from 0.57cm (PL-4) to 0.86cm (PL-3). However, the maximum pileus diameter of 7.96 cm was measured in PL-2, followed by PL-6 (6.97 cm) and PL-1 (6.7cm) and the pileus diameter of the remaining strains varied from 5.96 cm to 6.7 cm (Table 1).

(a) Strain PL-3 **(b) Strain PL-2**

Fig. 2. High yielding strains of oyster mushroom

Conclusion

From the research conducted, it can be concluded that the strains PL-2 and PL-3 of *Pleurotus species* exhibited substantial performance in terms of yield. Stipe length, stipe diameter and pileus diameter were crucial in attributing the morphological characteristics of different strains of oyster mushroom. By harnessing the palatable, beneficial, and pharmaceutical values of oyster mushrooms, rural communities can capitalize on their potential by utilizing agricultural, household, and industrial waste as substrates, not only minimizing environmental impact but also fostering economic development and self-sufficiency.

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Comparative nutritional values of dinanath grass and sweet sorghum fodder at the post-flowering stage for crossbred heifers

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ABSTRACT

The feeding value of dinanath grass with sorghum fodder at the post-flowering stage was compared. In the present study, sixteen crossbred heifers (274±11 d; 85.3±4.9 kg) were grouped in 8 pairs based on their age and live weight. One animal from each pair was randomly allotted to one of the two groups, T_1 and T_2. In T_1, the animals were offered dinanath grass fodder, whereas in T2, sorghum fodder was offered ad libitum and the fodders were enriched with urea at 0.4 and 0.2% on a fresh weight basis, respectively. They were also given 1 kg of concentrate mixture (40% wheat grain; 40% groundnut cake; 20% husk), 30 g of common salt, and 30 g of chalk daily for 13 weeks. The bodyweight of the animals was calculated by the weekly multiplication of the length (cm) and heart girth (cm) of the animal divided by 11200. After 21 days of adaptation, a 7-day digestibility trial was conducted to compare the intake and digestibility of nutrients. The samples were chemically analyzed for proximate principles using standard techniques. The data were subjected to statistical analysis using the paired 't' test. It can be concluded that dinanath grass and sorghum fodders are both equally inferior in nutritive value at the post-flowering stage and may not be continued for a long period as the sole feed without nutrient supplementation.

Keywords: ADG, Digestibility, Dinanath grass, Intake, Sorghum.

Introduction

The regional deficits in fodder are more important than the national deficit (Tiwari et al., 2016). The pattern of deficits varies in different parts of the country. To supply green fodder from one location to another is not feasible because of the involvement of transportation. In such conditions, locally available weeds, inland crops, or imported fodder crops play an important role in sustainable livestock production.

It is very difficult to increase the area under fodder crops because of the population pressure for food and fibre (Riaz et al., 2020). Fortunately, the Indian sub-continent is one of the world's megacenters of crop origin and crop plant diversity because of the availability of a wide spectrum of eco-climates. The Indian gene centre possesses rich genetic diversity in native grasses and legumes. Almost one-third of Indian grasses are considered to have fodder value for livestock. It is necessary to explore high-yielding fodder crops that may be suitable for cultivation in particularly green fodder deficit locations, evaluate locally available fodder crops, and improve them to overcome inferiority factors.

With profuse tillering capability, dinanath grass (*Pennisetum pedicellatum*) is a quick-growing, luscious, leafy, and thin-stemmed grass that grows well in poor, eroded soils in areas receiving 500–1500 mm of annual rainfall. It is a high-yielding, tall, annual, tufted perennial forage (Asmare et al., 2017). This crop is of short duration and fits well in the small period between two major crops. The grass thrives and performs well on a wide range of soils (including degraded sandy or ferruginous soils), provided they are well-drained (FAO, 2010). Because of its high fodder production potential and tolerance towards drought, insect and disease infestation, dinanath grass is becoming more popular day by day, but reducing the unwanted volume and extracting true seeds from spikelets for efficient post-harvest handling, transportation, and various farm operations is required for large-scale utilization of dinanath grass as forage for animals (Vijay et al., 2018). Maity et al. (2017) worked on layered pelleting of the nucleus seed of dinanath grass with soil and observed the highest germination of 91%. Seed yield of grasses is very low, while demand for seed upgrading of grasslands is high (Meena and Nagar, 2019). The feeding value of dinanath grass fodder at early and pre-flowering stages has been assessed and found to be similar to that of sorghum fodder (Kishore and Verma, 2000).

Keeping the above facts in consideration, the present experiment was conducted to compare the feeding value of dinanath grass with sorghum fodder at the post-flowering stage.

Materials and Methods

Dinanath grass (Variety T-10) and sorghum (Variety CSH-1) were grown at the farm at a suitable interval to maintain the stage of the plant at harvest for feeding, following standard agronomical practices. At the stage of post-flowering, the crops (dinanath grass: 90–110 days after sowing; sorghum: 80–90 days after sowing) were harvested for proximate analysis (AOAC, 2019) and used for the experimental feeding of animals.

Sixteen crossbred heifers (*Sahiwal x Jersey*) were selected at the dairy farm and grouped into 8 pairs based on their age (274±11 d; 85.3±4.9 kg). One animal from each pair was randomly allotted to one of the two groups, T_1 and T_2. In group T_1, the animals were offered dinanath grass, whereas in group T_2, they were given sorghum fodder *ad libitum*. As the crude protein content in dinanath grass (4.90%) and sorghum (5.16%) at the post-flowering stage was very low (Table 1), the fodders were enriched with urea at a rate of 0.4 and 0.2% on a fresh fodder weight basis in the T_1 and T_2 groups, respectively. They were also given 1 kg of concentrate mixture (40% wheat grain; 40% groundnut cake; 20% husk), 30 g of common salt, and 30 g of chalk daily.

The experimental heifers were housed in a large shed with partitions in the troughs for individual feeding. The fodder was offered to the animals in the morning and the concentrate mixture in the afternoon. The heifers were let loose in an open enclosure for 4 hours before feeding fodder. The animals had free access to drinking water.

Table 1: Chemical Composition at post flowering stage (%)

Nutrient	Dinanath grass		Sorghum fodder		Concentrate Mixture
	Enriched with urea		Enriched with urea		
	Without	With	Without	With	
DM	30.5	29.2	39.6	37.4	92.5
CP	4.90	7.00	5.16	8.04	16.9
EE	4.26	4.28	4.33	4.36	5.59
CF	38.9	38.3	36.7	36.2	18.1
NDF	68.3	67.0	65.6	64.2	51.3
ADF	39.4	39.0	33.7	32.	25.7
GE*	3.31	3.28	3.35	3.33	3.73
ASH	10.3	10.2	7.49	7.58	12.0
NFE	46.6	39.9	46.3	43.8	47.4
OM	89.7	89.9	92.5	94.4	88.0
AIA	2.79	2.78	3.05	3.02	3.09
H.Cell.	28.9	28.0	31.9	32.2	25.6
TCHO	80.5	78.5	83.0	80.0	65.5
** Mcal/kg*					

The bodyweights of the animals were calculated weekly based on body measurements, i.e., the multiplication of the length (cm) and heart girth (cm) of the animal divided by 11200. After 21 days of adaptation, a 7-day digestibility trial was conducted to find out the intake and digestibility of the nutrients. The collected samples were chemically analyzed for proximate principles using standard techniques. The data recorded during the experiment were subjected to statistical analysis using suitable methods (Snedecor and Cochran, 1994).

Results and Discussion

The contents of dry matter, crude protein, ether extract, gross energy, organic matter, acid insoluble ash, hemicellulose, and total carbohydrates were high and crude fibre, neutral detergent fibre, acid detergent fibre, ash, and nitrogen-free extract low in sorghum fodder in comparison to those in dinanath grass (Table 1). These results were found to be contrary to Kishore and Verma (2000), which could be due to the different stages of fodder harvesting. The ranges of nutrients in both fodders varied from the study of Tilahun et al. (2017), which may be because of the different conditions of growing dinanth grass. However, the findings confirmed the results of Chakrabarti et al. (1988). Because of enrichment with urea, the content of crude protein increased, which may be due to the high nitrogen content (46% in urea). The chemical composition showed very little variation with the observations of Sonawane et al. (2019), which could be due to different varieties of sorghum fodder.

The consistently but not significantly ($P > 0.05$) higher dry matter digestibility of dry matter in T_1 compared to that in T_2 is presented in Table 2, which confirms the results of Kishore and Verma (2000). Higher digestibility coefficients in T_1 in comparison to those observed in the literature (Jakhmola and Pathak, 1983) may be due to the enrichment of fodder with urea, which increased the CP content of the feed and hence enhanced microbial activities in the rumen ecosystem. It is a well-known fact that for the fullest expression of the potential digestibility of non-leguminous forages, the crude protein content of the diet should be 8 per cent. The digestibility coefficients of energy and fibre components, especially acid detergent fibre, were observed on the higher side in T_1 in comparison to those in T_2 and confirmed the findings of Kishore and Verma (2000).

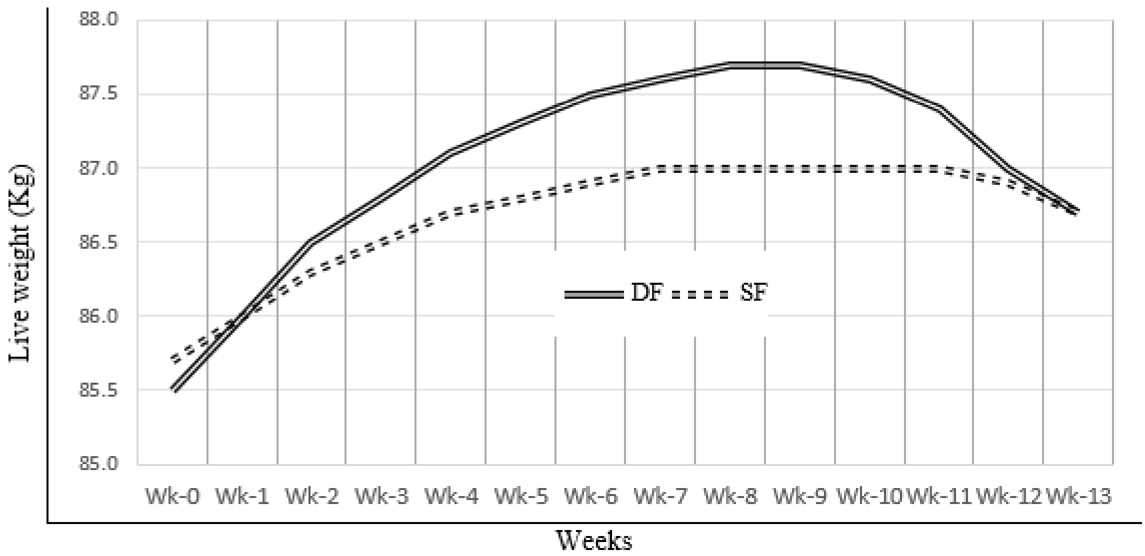
Table 2: Nutrient utilization Nutrient

Digestibility Coefficient			
Nutrient	**Unit**	**T1**	**T2**
DM	(%)	60.7±1.1	57.9±1.7
CP	(%)	68.6±1.0	64.3±1.3
CF	(%)	40.7±3.9	42.8±3.0
NDF	(%)	53.2±1.2	52.9±1.5
ADF	(%)	60.1±1.3	57.0±1.8
Gross Energy	(%)		
Intake			
DM	kg/100kg LW	2.17±0.10	3.31±0.18
	$g/kgW^{0.75}$	68.8±4.7	102±7
DDM	kg/100kg LW	1.87±1.00	1.73±0.9
	$g/kgW0^{.75}$	38.8±2.2	66.8±3.6
CP	kg/100kg LW	243±13	352±13
	$g/kgW^{0.75}$	7.19±0.30	10.76±0.5
DCP	kg/100kg LW	161±9	225±7
	$g/kgW^{0.75}$	4.94±0.28	6.89±0.26
DE	M cal/100kg LW	5.12±0.27	6.57±0.37
	$K cal/kgW0.^{75}$	134±7	190±11
Gains			
ADG	g/d	101±99.83	76±85.57

Significantly higher intakes of dry matter and crude protein were recorded in T_2 ($P < 0.05$) in comparison to T_1 (Table 2). The intake data in T_2 is in agreement with Randhawa et al. (1988). A higher intake of digestible nutrients like digestible dry matter, digestible crude protein, and digestible energy may perhaps be due to a higher intake of the nutrients. The present intake data was recorded in line with the results reported in the literature (Kishore and Verma, 2000).

The average daily gains in the two groups (Fig. 1) under study were non-significant ($P > 0.05$), despite significantly higher intake data in T_2. The average daily gain was showing a trend towards fall. The animals started losing weight in weeks 10 in T_1 and 12 in T_2. The reason for this declension could perhaps be due to the availability of nutrients in both fodders at the post-flowering stage.

Fig. Weight map of the experimental animals (kg)



Note: DF denotes T1, and SF T2.

It can be concluded based on this study that dinanath grass and sorghum fodder are both inferior in nutritive value in the post-flowering stage and should not be continued for a long period of time. If it is necessary to continue with these fodders, the diet should be enriched or supplemented with nutrients to meet the nutritional requirements of growing crossbred heifers.

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Evaluation of Lentil Genotypes for Resistance of *Fusarium oxysporum* f.sp. lentis

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Abstract

*Lentil (*Lens culinaris *Medikus Sub sp.* Culinaris*) is a highly nutritious pulse crop grown globally as a rainfed crop in the winter season and also a cheap source of protein for rural people. Fusarium wilt, caused by* Fusarium oxysporum *f.sp. lentis (Fol), is a major fungal disease that affects lentil crops, leading to a significant yield reduction. In this study, 50 lentil genotypes were screened against a highly aggressive Fol isolate (AGLF-11) under greenhouse conditions. Out of the tested genotypes, 14 showed high susceptibility, 29 showed moderate susceptibility, 5 exhibited moderate resistance and only 2 genotypes (L 7920 and DPL 58) showed resistance to the Fol isolate. Thus, the two genotypes (L 7920 and DPL 58) hold promise for breeding programmes aimed at developing lentil varieties with improved resistance to this devastating fungal disease, which could help mitigate yield reduction and ensure the continued cultivation of this highly nutritious pulse crop for ensuring nutritional security among rural people.*

Keywords: Lentil, Fusarium wilt, *Lens culinaris,* disease resistance.

Introduction

Lentil (*Lens culinaris* Medikus subsp. culinaris), also known as masur, is an annual, self-pollinated pulse crop grown worldwide as a rainfed crop in the winter season. It is highly nutritious, rich in protein, starch, micronutrients, and dietary fiber. Lentils are an excellent protein source, containing 192% more protein than mushrooms (Nayak et al., 2021; Nayak et al., 2022) but 2-3 times less protein per calorie than meat/ beef. Lentil protein bridges the nutritional gap in the diets of rural communities, providing a sustainable and affordable source of plant-based protein essential for their health and well-being. Lentil cultivation is prevalent in

India, with Bihar being a major lentil-growing state. However, lentil crops face various biotic and abiotic stresses, including Fusarium wilt caused by Fol, which results in significant yield loss (Vasudeva and Srinivasan, 1952). Fusarium wilt is a vascular disease that blocks nutrient and water transfer in plants, causing wilting and eventual death. Developing resistant cultivars is crucial for stable lentil production (Infantino et al., 2006). Due to limitations such as the confounding effects of drought and other root rot pathogens, field screening alone is insufficient. Therefore, it is necessary to conduct screening in controlled conditions in a glasshouse (Meena et al., 2017). Hence this study was carried out with specific objective of identifying lentil genotypes resistant to *Fusarium oxysporum* f.sp. lentis through greenhouse screening.

Materials and Methods

Fifty lentil genotypes from various sources were collected and screened against the highly aggressive Fol isolate AGLF-11 and the experiment were re-conducted for validation. The screening was conducted under controlled greenhouse conditions using sick soil micropots. The genotypes were evaluated for pre-germination and post-germination mortality. The experiment followed a completely randomized design with three replications per genotype. Disease rating scales were used to categorize genotypes based on their mortality percentages.

Detail of Fol isolate used

Highly aggressive Fol isolate, AGLF-11/Fol-11 was collected from major lentil growing region mainly collected from Tal area of Barh, Patna, Bihar, India in year 2019. Different Fol isolates have different morphological characteristics viz. white, light pink, pink and dark pink colony colour and sparse, fluffy, centrally fluffy and crystal growth patterns. The colony colour of this isolate is mainly pink with sparse growth pattern.

Greenhouse screening

AGLF-11 isolate was maintained in laboratory using potato dextrose agar (PDA) medium supplemented with streptomycin sulphate and stored in a refrigerator (4°C). Sub culturing of isolate was done time to time. The isolate was mass multiplicated as per the protocol of Kamdi et al. (2012) with necessary modifications. Initially sorghum grains were soaked in water overnight. Excess water was drained out and seeds were soaked in dextrose water @ 100g in 1 litre water. It is then spread and air dried on the clean blotting paper. Moistened grains (about 150 g) were filled in each autoclavable poly bags and autoclaved for 30 minutes at 15 lbs. psi pressure. The mycelium bit of pure culture of AGLF-11isolate was inoculated under aseptic condition in the poly bags containing grains and incubated for 12-14 days at 25±2°C. Meanwhile polybags were shaken regularly to facilitate early growth of the fungus or to avoid clumping of grains. Due to mycelial growth of the test fungus, the grains turned whitish.

To prepare sick soil micropots, the grains colonized by isolate were mixed in the soil (Bayaa and Erskine, 1990; Bayaa et al., 1995; Kamdi et al., 2012). Fusarium wilt susceptibility of each genotype was tested in infected soil. For this, sterilized sandy-loam soil was mixed with mass multiplied culture of AGLF-11 @100g/ kg soil. Seeds of 50 lentil genotypes were rinsed with distilled water. 10 Seeds of each lentil genotypes were sown in each well of the infected soil following Completely Randomized Design (CRD). The experiment was carried out in three replications for each genotype. Controlled soil micropot was also used without AGLF-11 isolate infection with each genotype. Observations on pre-germination mortality and post--germination mortality percentage were recorded up to 15 days. The post emergence mortality was recorded time to time and the final data was recorded at the end of the experiment on 15th day.

The pre germination mortality and post germination mortality percentage were recorded using following formula:

The genotypes on the basis of mortality percentage recorded were categorized into different categories, viz., immune resistant, moderately resistant, moderately susceptible and highly susceptible, on a scale of 1 to 9 (Stoilova and Chavdarov, 2006) (Table 1).

$$Pre\ germination\ mortality\ (\% = \frac{\text{Total germination of healthy seeds} - \text{Total germination of treated seeds}}{\text{Total germination of healthy seeds}} x100$$

$$Post\ germination\ mortality\ (\%) = \frac{\text{Total germination of treated seeds} - \text{Plant survived in treated seeds}}{\text{Total germination of treated seeds}} x100$$

Where complete yellowing and dropdown of the plants were considered complete mortality of the plants.

Table 1: Disease rating scale for Fusarium wilt

Sl. No.	Rating	Mortality (%)	Disease reaction
1.	1	≤ 1 %	Immune (I)
2.	3	2-10 %	Resistant (R)
3.	5	11-20 %	Moderately resistant (MR)
4.	7	21-50 %	Moderately susceptible (MS)
5.	9	>50 %	Highly susceptible (HS)

Results and Discussion

The screening results revealed a wide range of pre-germination and post-germination mortality percentages among the tested lentil genotypes. The genotypes exhibited varying levels of susceptibility or resistance to the Fol isolate. Among the tested genotypes, 14 were highly susceptible, 29 were moderately susceptible, 5 exhibited moderate resistance, and only 2 genotypes (L 7920 and DPL 58) showed resistance to the AGLF-11 isolate. These resistant genotypes hold promise for developing wilt-resistant lentil varieties.

Under controlled conditions, the reactions of several lentil genotypes to the AGLF-11 isolate of *Fusarium oxysporium* f. sp. lentis

After the experiment was completed, genotypes of lentil plants were tested based on their reactivity to the AGLF-11 isolate. The screening resulted in the lentil genotypes being classified into four separate groups: resistant, moderately resistant, moderately susceptible, and extremely susceptible. L 7920 and DPL-58 were resistant among the fifty genotypes tested, whereas HUL-57, PL-639, L 4717, L 4147, and L 4771 were somewhat resistant. The genotypes JL-3, P-13108, Noori, GP 3221, Moitree, BRL-2, DBGL-105, DBGL-135, IG-195, IG 122133, P-15115, JL-1, JL-7, P43120, IG-55983, NDL-I, MC-6, Flip-96-51, PL-6, PL-8, PL-27, KLS-218, Pusa Ageti, IPL-406, DPL-15, PL-406, IPL-321, K-75, and PL-05 indicated moderate susceptibility. LKH-I, Titua, VL-138, Pusa Vaibhav, DBGL-62, P-3236, DKL-37, DPL-62, IPL-316, IPL-526, BRL-3, Shivalik, IPL-81, and PL-04, on the other hand, showed high susceptibility reactivity to the AGLF-11 isolate. There was no immunological response in any of the genotypes.

Table 2. Reactions of lentil genotypes against Fusarium wilt (AGLF-11 isolate) in controlled conditions

Rating scale	Reaction	Mortality (%)	Genotypes
1	Immune (I)	≤ 1 %	Nil
3	Resistant (R)	2-10 %	L 7920, DPL-58
5	Moderately resistant (MR)	11-20 %	HUL -57, PL-639, L 4717, L 4147, L 4771
7	Moderately susceptible (MS)	21-50 %	JL-3, P-13108, Noori, GP 3221, Moitree, BRL-2, DBGL-105, DBGL-135, IG-195, IG 122133, P-15115, JL-1, JL-7, P43120, IG-55983, NDL-I, MC-6, Flip-96-51, PL-6, PL-8, PL-27, KLS-218, Pusa Ageti, IPL-406, DPL-15, PL-406, IPL-321, K-75, PL-05
9	Highly susceptible (HS)	>50 %	LKH-I, Titua, VL-138, Pusa Vaibhav, DBGL-62, P-3236, DKL-37, DPL-62, IPL-316, IPL-526, BRL-3, Shivalik, IPL-81, PL-04

The effective screening of genotypes was dependent on the accumulation of critical knowledge about the biology and interaction of the host and pathogen (Beniwal et al., 1993; Bhat et al., 2006; Chandra et al., 2019; Choudhary et al., 2013). The use of known tests in both field and greenhouse conditions aided in the identification and selection of lentil plants with wilt resistance (Meena et al., 2017). The genotypes identified as resistant through screening might be useful sources of resistance for developing wilt-resistant lentil varieties in future studies. Furthermore, the cloning of resistance genes using differential display expression analysis shows promise for future advances in this field.

Conclusion

Fusarium wilt caused by Fol is a significant threat to lentil production worldwide. Screening lentil genotypes for resistance to highly aggressive Fol isolates is essential for developing wilt-resistant cultivars. In this study, two lentil genotypes (L 7920 and DPL 58) exhibited resistance to the AGLF-11 isolate, indicating their potential for breeding wilt-resistant varieties, which could help mitigate yield reduction and ensure the continued cultivation of this highly nutritious pulse crop for ensuring nutritional security among rural people. Further research is needed to understand the genetic basis of resistance and develop effective breeding strategies to combat Fusarium wilt in lentil crops.

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Dairy husbandry: the contribution of different species to the earnings of small farmers

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Abstract

Dairy husbandry has excellent potential for ensuring food security for small farmers in India. However, this sector has been facing various challenges, such as a poor genetic base, a scarcity of feed resources and inadequate health care services. Genetic breeding to produce a higher milk yield plays a very significant role in increasing the profitability of dairy animals. Indian farmers presently have options to maintain different types of milking animals, such as nondescript cows with a very low milk yield of 1–2 kg milk per day, cows of recognized indigenous breeds, with the average daily milk yield ranging between 2 and 6 kg/day, crossbred cows with 6–8 kg/day, or buffaloes of nondescript or recognized breeds, with an average milk yield of 3–6 kg/day. Although the average milk yield is a reliable parameter for the selection of dairy animals, farmers are either compelled by their ability to invest in high-milking animals or influenced by the information available to these types of animals about their ability to adapt to local climatic conditions, their ability to tolerate heat stress and diseases, and the quality of milk before making their choice. However, in the absence of valid facts, many farmers end up making the wrong choice of animals and fail to optimize their income. This paper reviews the merits of different types of milking animals to enable them to make the proper choice.

Key words: Buffalo verses cow, Comparative benefits, Comparative milk yields, Crossbred cows, Quality of milk.

Dairy husbandry: supplementary income for small farmers

Dairy husbandry has been an important source of income for most of the small farmers in India. Traditionally, small farmers have been maintaining cattle more to support agriculture through manure, bullock power and milk for home consumption, while buffaloes are maintained by wealthy farmers in fertile agricultural areas. In the absence of good infrastructure for breeding, health care, milk processing and marketing services, it has been difficult to increase milk production in spite of the growing demand. Hence, these livestock have been in a state of neglect, resulting in severe genetic erosion of precious Indian cattle breeds across the country.

In 1951, India had 155.3 million cattle, including 54.4 million adult females, which yielded 7.3 MT of milk and 43.4 million buffaloes, including 21 million adult females, which yielded 9.7 MT of milk. Over 80 per cent cattle were nondescript, with an average yield of 150 litres of milk per annum. The annual growth in the dairy sector was less than 1 per cent. For the increasing number of small landholders, crop production alone was not adequate to earn their livelihood and maintaining bullocks for tilling was uneconomical. Hence, the strategy was to promote dairy husbandry for supplementary income. During the 1960s, to improve the progeny of these nondescript cattle, cross-breeding with international dairy breeds was considered a better option, as upgrading with native breeds would have taken several generations to enhance milk production. This programme of cross-breeding nondescript cattle gave a boost to the dairy husbandry programme. Simultaneously, conservation of native breeds was also given due importance. In 40 years, i.e., from 1960 to 2009-10, dairy husbandry in India was a significant success story, with annual milk production increasing by 6.85 times to attain 116.425 MT and benefiting over 105 million rural households.

Baseless narratives on cattle breeds

The programme of upgrading the progeny of nondescript cattle through cross-breeding enabled poor farmers to produce superior progeny without heavy investment and earn their livelihood with only 2–3 cows. During the period 2005–2016, the dairy husbandry sector registered a growth rate of 63 per cent. However, in 2012, the dairy sector in India was hit by a rumour that A1-type milk produced by exotic breeds of cattle and crossbreds with exotic blood can cause several deadly diseases like diabetes type 1, coronary heart disease, autism, schizophrenia, and sudden infant death syndrome (SIDS). This report was merely based on some international reports published in the 1990s and the book 'Devil in the Milk', published in New Zealand in 2007, although the European Food Safety Authority (EFSA) in 2009 rejected these claims due to a lack of evidence and stated that both A1 and A2 types of milk were equally safe. This baseless adverse report on A1-type milk gave a boost to certain lobbyists who had been advocating a ban on the use of exotic breeds in India. These groups simultaneously sent various narratives about the nutraceutical and medicinal value of milk, ghee, urine and dung from different native cattle breeds. This created major confusion among cattle owners across the country and many farmers were directionless about the economics of different dairy animals (Hegde, 2019). To make matters worse, neither the government agencies nor the scientific institutions in the country made any attempt to enlighten the public about reality and the need to ignore these unscientific facts. However, a declaration made by the Department of Animal Husbandry, Government of India, in 2021 that 'the adverse reports circulated earlier against A1 type milk were baseless and both A1 and A2 types of milk were safe' provided some comfort to dairy farmers as well as to milk consumers. However, issues such as the advantages of Indian native breeds versus crossbred cows, comparative economics and the quality of milk from different breeds and species still remain unclear among most of the farmers, while government agencies continue to encourage the farmers to maintain native breeds of cattle.

Suitability of different species and breeds of livestock for milk production

Presently, dairy farmers have to take several factors into consideration while selecting dairy animals from different breeds of cattle and buffalo. The options available for them are either cows or buffaloes and among cows, there are different breeds of native cattle or crossbreds of different exotic breeds with different blood levels. Among buffalo breeds, there are several good breeds that originated in different regions. For small farmers, although the primary consideration for maintaining an animal is higher income, other factors such as adaptability to the local ecosystem and feed resources, tolerance to diseases, demand for milk and ease in trading and disposal of unproductive animals will also influence the choice of animals for milk production.

Economics of Different Bovine Breeds: Table 1 presents the average daily milk yield of different livestock species. During the year 2020–21, the average daily milk yield has been highest in exotic cows [9.15 kg], followed by crossbred cows [7.22 kg], indigenous breeds of buffaloes [6.41 kg] and nondescript buffaloes [4.13 kg], while the nondescript cattle yielded the lowest quantity of milk [2.71 kg]. During the year 2020–21, buffaloes contributed 45 percent of the total milk as against 49 percent in 2015–16, whereas crossbred cows contributed 28 percent to the total milk production. This confirms that the rate of increase in species-wise milk production has been highest in crossbred cows during the last five years, while the contribution of milk from native cattle has been stable at 20 percent (GOI, 2022).

Table 1. Species-wise average daily milk yield for different species of livestock in India

Sr. No.	Species	% of Total **Milk Production** 2015-16	Yield Kg/day	
			2015-16	2020-21
1	Buffalo indigenous	35	5.76	6.41
2	Buffalo non-descript	14	3.80	4.13
3	Cow indigenous	11	3.41	3.34
4	Cow non-descript	9	2.16	2.71
5	Cow cross-bred	26	7.33	7.22
6	Cow exotic	1	11.21	9.15
7	Goat	3	0.45	0.47

Source: Government of India (2017, 2022)

It has also been reported that the lactation yield of Indian breeds of cows has increased from 913 kg/lactation in 2013-14 to 993 kg in 2020-21, whereas the yield of buffaloes during the same period has increased from 1792 kg to 2061 kg (GOI, 2022). This data indicates that the productivity improvement has been higher in buffaloes than in indigenous breeds of cattle, while the productivity of crossbred cows has been stable at 2165 kg/lactation. It can also be observed that the average milk yield of buffalo has reached very close to the average yield of crossbred cows, with the potential to compete with each other.

The economics of different types of crossbred cows and buffaloes have been studied in different regions of the country. In a study conducted by BAIF, the net income from crossbred cows per annum was Rs. 25039, while the net returns from Gir and nondescript cows were Rs. 15115 and Rs. 6335 per year, respectively [personal communication]. In Rajasthan, the net returns from Holstein Friesian cross-bred cows were highest at Rs. 56116 per year as compared to Rs. 30101 from Jersey cross, Rs. 13550 from buffalo and Rs. 5098 from local cows, as presented in Table 2. In Western Maharashtra, the net average income from crossbred cows was Rs. 37,767 as compared to Rs. 20,029 per year from Pandharapuri buffalo [Hile *et al*. 2018]. Hence, crossbred cows had higher economic benefits than cows of native breeds and buffaloes. Among the buffaloes, Murrah has been the most popular breed, widely accepted for upgrading the nondescript buffaloes and even for crossing with other local breeds. Jaffrabadi and Surti breeds of buffalo were also popular in Western India because of their high butterfat content in milk and lower feed requirements, respectively.

Table 2. Comparative performance of cows and buffaloes in Rajasthan

Bovine Category	Net Returns Rs./ Year/Head	Cost of Milk Production Rs./Lit	Return Rs./Lit
Local cow	5098	20.40	2.26
H. F. Cross	56116	11.86	10.55
Jersey Cross	30101	14.86	7.57
Buffalo	13550	21.19	4.40

Source: Kumawat *et al.* 2016

Among crossbred cows, HF crosses have been yielding more than the crossbreds of Jersey and other exotic breeds. Among the crossbreds, daughters born to indigenous dams with a genetic background of milch and dual-purpose breeds have been performing better than those born to nondescript or draught breeds. Among the milch breeds of cattle, Sahiwal and Gir were more popular, mostly because of their higher milk yields. As the population of these breeds is larger than that of many other breeds (Table 3), animals of these breeds can be easily procured in the market. The population of the other two milk breeds, namely Tharparkar and Red Sindhi, is very small and hence, it is difficult to procure good animals from the market except in their home tracts. There are five dual-purpose breeds that yield in the range of 1000 and 1500 kg/lactation and these breeds are popular mostly in their home tracts. The economics of dual-purpose and draught breeds are not clear because of lower milk yields and a heavy reduction in the usage of bullocks for tillage purposes, which has come down from over 55 percent to less than 8 per cent farmers over the last 30 years. Hence, farmers wanting to own native breeds of cattle are ignorant as to how to select suitable cattle for enhancing their income. Presently, the farmers wanting to maintain cows of indigenous breeds have been procuring cows of popular milk breeds such as Gir and Sahiwal at a very high cost and have not been able to obtain the expected results. Farmers maintaining dual-purpose or low-yielding draught breeds are being advised to conserve them as pure breeds, which certainly is not a viable income-generating activity in the present context. The Government of India has also not issued any guidelines about the economic management of draught breeds of cattle and it is not fair to expect innocent farmers to take on the burden of conserving them.

Table 3. Population of cattle of indigenous milch and dual-purpose breeds

Sl. No.	**Breed Name**	**Pure [lakh]**	**Graded [lakh]**	**Total [lakh]**	**% of Total Descript breeds**
Milch Breeds [Milk Yield above 1500 kg]					
1	Gir	13.802	37.328	51.130	3.38
2	Sahiwal	10.195	37.900	45.623	3.23
3	Tharparkar	1.973	5.352	7.325	0.48
4	Red Sindhi	0.596	4.977	5.574	0.37
Dual Purpose [Milk yield 1000 -1500 kg]					
1	Kankrej	19.451	10.832	30.383	2.00
2	Haryana	16.392	46.408	62.800	4.15
3	Rathi	8.659	3.716	12.375	0.82
4	Ongole	1.159	5.186	6.345	0.42
5	Dangi	1.194	0.744	1.938	0.13
Indigenous Breed Cattle		**178.490**	**200.703**	**379.192**	**25.06**
Non-Descript				**1132.531**	**74.92**
Total Indigenous Cattle		**178.490**	**207.703**	**1511.723**	**100**

Source: GOI (2013)

In the last five years, many farmers have shifted from cross-bred cows to native breeds of cattle, mainly because of the publicity surrounding the utility of their milk and urine for medicinal uses and their superior quality. Although scientific studies have reported that the chemical composition of milk, particularly the phytochemicals present in milk and urine, is completely dependent on the feed they consume, irrespective of the breed, certain groups are making tall claims about their medicinal value without any valid proof. With regard to the nutritional value of milk, cow's milk was considered superior to buffalo's milk because of its high butterfat content, which is heavy for digestion, as presented in Table 4. However, buffalo milk, with its high protein and calcium content and low cholesterol, can be healthier than cow milk if 3–4 per cent fat is removed by using a cream separator without affecting the other qualities. Another advantage for buffalo owners is the easy disposal of uneconomical animals. Farmers in many regions have already been facing the problem of selling their cattle which has forced them to shift from cows to buffaloes for milk production. With higher price realization for buffalo milk and increasing milk yield, farmers are seeing brighter prospects in buffalo husbandry over cattle, although crossbred cows with higher milk production and a lower cost of production are more economical in most parts of the country.

Table 4. Comparative nutritive value of milk

Traits	Cow	Buffalo	Goat
Total solids, %	13.10	16.30	12.48
Fat, %	4.30	7.90	3.8
Protein, %	3.60	4.20	2.9
Lactose, %	4.80	5.00	4.08
Tocopherol, mg/g	0.31	0.33	
Cholesterol, mg/g	14.00	8.00	11.00
Calcium, mg/100 g	165	264	134
Phosphorus, mg/100 g	213	268	
Magnesium, mg/100 g	23.0	30.0	
Potassium, mg/100 mg	185.0	107.0	204
Sodium, mg/100 g	73	65	50
Vitamin A (+ Carotene) IU/gm fat	30.30	33.00	39.0
Vitamin C, mg/100 g	1.90	6.70	2.0

Source: Dhanda (2006)

Goat milk is another source of milk, contributing 3 percent to the annual milk production in the country. While the national average yield of goats is 0.47 kg per day, the Surti breed has the highest average yield of 2.5 kg per day, followed by Zalawadi (2.02 kg per day), Kutchi (1.84 kg per day), and Gohilwadi (1.71 kg per day). However, dual-purpose breeds like Jamnapari, Beetal, Sangamneri and Sirohi are also popular among goat keepers. Although adequate data on dairy goat husbandry is not available, preference may be given to goats with a higher milk yield to generate additional income from milk along with meat production.

Policy support required to improve the income of dairy farmers

As dairy farmers are ignorant about many technical aspects of managing different species of dairy animals, scientists and the government have to provide correct technical information and suitable policy support. Following are the important issues that need to be addressed to strengthen the dairy husbandry sector in the country:

- **Suitable Breeding Policy and Advocacy:** While giving priority to the conservation of Indian breeds for improving the progeny of nondescript cattle, farmers may be given the choice to adopt cross-breeding or upgrading with native breeds by explaining the economics of these cows. Ideally, crossbreeding for the first progeny and backcrossing the crossbred cows with any elite Indian dairy breed can produce superior cows with high milk yield and good Indian stress tolerance qualities, like Gir cows in Brazil. The policy regarding conservation of draught breeds and permitting low-yielding cows to be bred with any elite Indian or exotic breed may also be explored. A user-friendly knowledge portal may be established to provide authentic information on good husbandry services and the performance of different breeds of livestock and the medicinal value of milk, ghee, urine, etc. with valid proof.

Table 5. Average milk yield of different breeds of goats

Breed	**Habitat**	**Body Wt. (Kg)**		**Milk**
Dual-purpose breeds (milk and meat)		**Male**	**Fem.**	**Kg/day**
Barbari	Agra, Mathura, Etah in U.P.	37.9	22.6	0.71
Beetal	Gurdaspur, Amritsar in Punjab	59.1	35.0	0.95
Gohilwadi	Bhavnagar, Amreli in Gujarat	37.1	36.0	1.71
Jakhrana	Alwar in Rajasthan	57.8	44.5	0.99
Jamunapari	Etawah in U.P.	44.7	38.0	1.06
Kutchi	Kutch district in Gujarat	43.5	39.3	1.84
Malabari	Kozhikode and Kannur in Kerala	39.0	31.1	0.31
Marwari	Western Rajasthan	33.2	25.9	0.53
Mehsana	Mehsana, Banaskantha in Gujarat	37.1	32.4	1.32
Sirohi	Sirohi and Ajmer in Rajasthan	50.4	22.6	0.41
Surti	Surat and Vadodara in Gujarat	29.5	32.1	2.50
Zalawadi	Surendranagar, Rajkot in Gujarat	38.8	33.0	2.02
Sangamneri	Ahmednagar in Maharashtra	38.4	29.0	0.82
Berari	Vidarbha region in Maharashtra	36.0	33.0	1.00

Source: Hegde (2020)

- **Reproduction and Health Care Services:** As male cattle are not useful to small farmers, the modern technology of using sexed semen should be encouraged to produce only female calves. Several laboratories have already started producing sexed semen in India, but farmers are reluctant to pay a higher price for the semen. Therefore, till the farmers are convinced to pay the real cost, the government may consider subsidization of the cost of sexed semen and making it available to farmers at Rs. 200–250 per dose during the next 3-5 years.

- Infertile cows and buffaloes cause huge losses to farmers. However, most farmers neglect this aspect. Thus, programmes like infertility camps followed by oestrous synchronization campaigns at village and block levels may be promoted to bring all the cows into the breeding cycle. Cattle health and production are often neglected by farmers due to the non-availability of veterinary services at their doorsteps. Schemes for promoting self-employed para-vets should be launched with training and credit facilities for those who can work under the supervision of veterinarians from the government or local dairy. With modern tools and diagnostic kits, para-vets may be allowed to carry out diagnostic and minor vet-care services, as farmers have great difficulty availing themselves of the services of veterinarians.
- **Shifting Dairy Husbandry to a Priority Sector:** Dairy development should be considered a priority sector to obtain the required loan at a lower rate. Funds should be made available for the purchase of animals and equipment as well. Soft loans should also be made available to new entrepreneurs who are interested in developing start-ups in the livestock sector, such as those providing critical services for the processing and marketing of dairy products and livestock. To motivate small dairy farmers and transfer new technologies, suitable farmers' organizations should be formed as cooperatives or farmers' producer companies at the village or block level that can establish efficient value chains.
- **Promotion of *Goshalas:*** Block Level *Goshalas* should be promoted by engaging farmers' organizations and civil society organizations that are interested in producing organic manure and using cow urine and dung for plant protection to boost organic farming. Suitable breeding and management support may be provided to transform these units into income- and employment-generating units for the local population. These units can collect unwanted animals from farmers to reduce their burden. The *Goshalas* may be encouraged to produce superior-quality farmyard manure by using locally available biomass as bedding material in the cattle sheds and mixing it with dung slurry and suitable microbes to improve the manure quality while reducing the gestation period.

Conclusion

From the available data about the performance of different milking species and breeds and the preferences of small farmers, it can be concluded that crossbred cows have been very popular among small farmers because they were able to produce highly productive cows by breeding their uneconomic, nondescript cows without any capital investment. Crossbred cows have been widely adapted to diverse ecosystems and millions of small farmers and even landless families with 2-3 such high-yielding cows have been able to come out of poverty. However, in the recent past, there has been a gradual shift from cattle to buffalo husbandry because of significant improvements in milk yield, a higher price for milk and ease in disposing of uneconomical animals. Greater awareness about the nutritional benefits of buffalo milk can further increase the popularity of buffaloes in the country.

In an effort to conserve native breeds of cattle, there has been an aggressive campaign urging farmers to maintain Indian native breeds by highlighting various benefits and special uses of milk and urine without scientific validation. In response to these recommendations, many farmers have started replacing crossbred cows and buffaloes with Indian breeds of cattle, which is bound to result in a significant reduction in income in due course. Therefore, it is necessary to develop a suitable policy to conserve precious native breeds involving government institutions instead of shifting the burden on farmers. There is also good scope to promote dairy goats under the goat development programme across the country.

As dairy husbandry has a proven track record, its potential can be fully harnessed by promoting farmer-friendly policies to ensure employment generation and food security for small farmers across the country, particularly in regions with a higher rate of poverty.

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Mushrooms: a review of health benefits, cultivation techniques, and nutritional analysis

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Abstract

The nutritional content of mushrooms, as well as the possible health advantages of mushrooms, are gaining widespread awareness around the globe. This paper provides an overview of the nutritional profile of Pleurotus mushrooms as well as production methods and prospective applications for these mushrooms. The advantages to health, such as the existence of bioactive substances, therapeutic characteristics, and hypolipidemic effects, are discussed in the article. It is emphasized that Pleurotus species are capable of growing on a wide variety of agro-wastes and lignocellulosic materials, and a number of various culture substrates and growth circumstances are explored. In addition, the essay examines the significance of genetic identification and fingerprinting techniques for the purpose of both the enhancement of strains and the manufacture of commercial quantities. The practices of environmentally responsible farming as well as the methods used by indigenous peoples for mushroom growing are discussed. In general, this article enlightens the reader on the nutritional and health benefits of Pleurotus mushrooms, as well as their potential for production and their function in environmentally responsible agriculture.

Keywords: Mushrooms, Health benefits, Cultivation techniques, Nutritional analysis, *Pleurotus species*.

Introduction

Because of their nutrient profile and the possible health advantages they may offer, mushrooms have garnered a substantial amount of interest in recent years. Pleurotus mushrooms, which are commonly referred to as oyster mushrooms, are one of the most well-liked and frequently farmed varieties of edible mushrooms. They provide a significant amount of essential nutrients as well as bioactive substances, both of which are beneficial to human health and wellbeing (Khan and Tania, 2012). In many different cultures, pleurotus mushrooms have a long history of both culinary and medical usage (Guzman, 2000). The purpose of this review article is to offer a summary of the nutritional profile, production methods, and possible uses of Pleurotus mushrooms.

Composition in terms of nutrition and advantages to one's health

Mushrooms belonging to the genus Pleurotus are well-known for the high levels of protein, dietary fibre, vitamins, and minerals that they contain (Khatun et al., 2015). They also include bioactive substances such as polysaccharides and phenolic compounds, both of which have been connected with a variety of positive health effects (Khan and Tania, 2012). According to research, pleurotus mushrooms have qualities that make them effective against cancer, antimicrobial infections, and antioxidants (Golak-Siwulska et al., 2018). They have been shown to have hypolipidemic and hypoglycaemic effects, which make them useful for people who have hypercholesterolemia (Raman et al., 2014) and diabetes (Nayak et al., 2021).

Other Mushroom Species and Their Health Benefits

Agaricus species

Agaricus species, including the commonly consumed *Agaricus bisporus*, also known as button mushrooms, possess a favourable nutritional composition and offer several health benefits. They are a good source of protein, dietary fibre, vitamins (such as riboflavin, niacin, and pantothenic acid), minerals (including potassium, phosphorus, and selenium), and antioxidants (Mshandete and Cuff, 2008; Rodriguez et al., 2007). Button mushrooms have been associated with potential anti-inflammatory and anti-cancer effects. They contain bioactive compounds like beta-glucans and conjugated linoleic acid, which have been shown to modulate immune function and inhibit tumour growth (Zhang et al., 2004; Golak-Siwulska et al., 2018).

Lentinula edodes (Shiitake mushroom)

Shiitake mushrooms have a long history of medicinal use and are well-regarded for their health benefits. They are rich in protein, dietary fibre, vitamins (particularly vitamin B complex), and minerals (such as copper, manganese, and zinc) (Mehmet and Sevda, 2010) (Akinmusire et al., 2011). Shiitake mushrooms contain bioactive compounds like lentinan, eritadenine, and beta-glucans, which have been linked to immunomodulatory effects, antiviral properties, and cholesterol-lowering activity. These mushrooms have also been studied for their potential to inhibit cancer cell growth and reduce the risk of cardiovascular diseases (Croan, 2004; Hoa and Wang, 2015).

Auricularia species

Auricularia mushrooms, commonly known as wood ear mushrooms, have gained recognition for their health-promoting properties. They are low in calories and fat but provide a notable amount of dietary fibre, protein, vitamins (particularly vitamin B complex), and minerals (including iron, zinc, and potassium) (Apetorgbor et al., 2013) (Sardar et al., 2017). Auricularia species contain bioactive compounds like polysaccharides, flavonoids, and phenolic compounds, which exhibit antioxidant, antitumor, and hypoglycemic activities. These mushrooms have been studied for their potential to enhance immune function, lower blood glucose levels, and prevent oxidative stress-related diseases (Girmay et al., 2016; Liao et al., 2018).

Flammulina velutipes (Enoki mushroom)

Enoki mushrooms, scientifically known as *Flammulina velutipes*, have a delicate texture and a distinct flavour. They are low in calories and fat but rich in dietary fibre, vitamins (especially vitamin B complex), and minerals (such as copper, selenium, and potassium) (Singh et al., 2011; Zmitrovich and Wasser, 2016). Enoki mushrooms contain bioactive compounds like beta-glucans and polysaccharides, which have shown immunomodulatory, anticancer, and antimicrobial properties. These mushrooms have been studied for their potential to enhance the immune response, inhibit tumour growth, and protect against microbial infections (Stamets, 2000; Zhang et al., 2019).

Other commercially important mushroom species

Several other mushroom species have also been recognized for their health benefits. *Hericium erinaceus*, commonly known as the "lion's mane mushroom, is known for its potential neuroprotective effects and is being studied for its role in promoting brain health (Sekan et al., 2019). *Ganoderma lucidum*, also known as reishi mushroom, is highly regarded in traditional Chinese medicine for its immune-modulating properties and potential anti-cancer effects (Yamanaka, 2011). *Cordyceps sinensis*, a parasitic fungus, is used in traditional Chinese medicine for its purported energy-boosting, anti-fatigue, and aphrodisiac properties (Berch et al., 2007).

In addition to the mushroom species discussed earlier, there are several other commercially important mushroom species that offer various health benefits. Let's explore some of them:

Hericium erinaceus (Lion's Mane Mushroom)

Hericium erinaceus, commonly known as the "lion's mane mushroom, is a unique-looking mushroom with long, dangling spines. It has gained popularity in recent years due to its potential health benefits, particularly for brain health. Lion's mane mushrooms are a rich source of bioactive compounds such as hericenones and erinacines, which are believed to promote nerve growth factor (NGF) synthesis in the brain (Stamets, 2000).

Research suggests that the lion's mane mushroom may have neuroprotective effects and could potentially enhance cognitive function. Studies conducted on animals have shown promising results, indicating that lion's mane extract may help improve memory and learning abilities (Guo et al., 2007; Tolera and Abera, 2017). However, further research is needed to determine its effectiveness in humans and the specific mechanisms involved.

Ganoderma lucidum (Reishi Mushroom)

Ganoderma lucidum, commonly known as the reishi mushroom, has been revered in traditional Chinese medicine for centuries due to its potential health benefits. Reishi mushrooms have a unique appearance, with a shiny, reddish-brown cap and a woody texture. They are known for their immune-modulating properties and have been studied for their potential anticancer effects (Choi and Kim, 2003).

Reishi mushrooms contain bioactive compounds such as triterpenes, polysaccharides, and antioxidants, which contribute to their medicinal properties. These compounds have been found to stimulate the immune system, enhance the activity of natural killer cells, and inhibit the growth of cancer cells in laboratory studies (Ijeh et al., 2009; Kibar and Peksen, 2008). Reishi mushrooms may also have anti-inflammatory and antioxidant effects, which could potentially support overall health and well-being (Naraian et al., 2009).

Cordyceps sinensis **(Cordyceps mushroom)**

Cordyceps sinensis is a unique mushroom that grows by infecting the larvae of insects, particularly caterpillars. It has a long history of use in traditional Chinese medicine and is known for its purported energy-boosting and anti-fatigue properties. Cordyceps mushrooms are rich in bioactive compounds such as cordycepin, polysaccharides, and adenosine, which are believed to contribute to their health benefits (Owaid et al., 2015; Ho et al., 2020).

Research suggests that cordyceps mushrooms may enhance physical performance and endurance by improving oxygen utilization and increasing ATP production in the body (Yang et al., 2013; Xiao et al., 2011). They have also been studied for their potential antioxidant, anti-inflammatory, and anti-ageing effects (Choi et al., 2018). Additionally, cordyceps mushrooms may have immunomodulatory properties, potentially supporting the immune system's function (Salehi, 2019). However, it's worth noting that most studies on cordyceps mushrooms have been conducted on animals, and more research is needed to fully understand their effects on humans.

These are just a few examples of commercially important mushroom species that offer unique health benefits. Each mushroom species has its own distinct composition of bioactive compounds, which contributes to their potential therapeutic properties. Incorporating a variety of mushrooms into the diet can provide a diverse range of nutrients and bioactive compounds, supporting overall health and well-being. However, it's important to note that individual responses to mushrooms may vary, and consulting with a healthcare professional is advisable before incorporating them into your diet.

These various mushroom species provide a range of health benefits due to their unique nutritional composition and bioactive compounds. Incorporating mushrooms into the diet can contribute to a well-balanced nutritional intake and potentially support overall health and well-being.

Cultivation Techniques

Mushrooms belonging to the genus Pleurotus may be grown on a diverse selection of substrates, including agro-wastes and lignocellulosic materials (Khan and Tania, 2012). These mushrooms are able to cultivate themselves using a wide variety of agricultural by-products, including paddy straw, corn-based media, vegetable waste, and grasses (Singh and Singh, 2011; Bumanlag et al., 2018). Techniques for cultivation include preparing the substrate, inoculating the spawn, and maintaining environmental conditions in regulated settings (Shukla and Biswas 2000). When it comes to producing good yields, one of the most important factors is optimizing the growth parameters, which include temperature, humidity, and light levels (Bumanlag et al., 2018).

Mushroom cultivation involves creating the optimal conditions for mushrooms to grow and develop. There are various cultivation techniques used, depending on the mushroom species and desired outcomes. Let's delve into some of the commonly employed cultivation techniques:

Substrate Preparation

The first step in mushroom cultivation is preparing the substrate, which serves as the growing medium for the mushrooms. Different mushroom species have specific substrate requirements. Commonly used substrates include agricultural waste materials such as straw, wood chips, sawdust, and agricultural residues. The substrate needs to be processed to remove contaminants, enhance its nutritional content, and create a favourable environment for mushroom growth.

Substrate preparation methods may involve sterilization, pasteurization, or a combination of both. Sterilization involves subjecting the substrate to high temperatures using steam or autoclaving to eliminate all microorganisms. Pasteurization, on the other hand, involves heating the substrate to lower temperatures to kill most microorganisms while preserving beneficial ones. Substrate preparation techniques aim to create a sterile or semi-sterile environment that is conducive to mushroom colonization and growth (Feeney et al., 2014).

Spawn Production

Spawn is the mycelium of the mushroom species that serves as the inoculum for mushroom cultivation. It is typically grown on a substrate such as grains (e.g., wheat, rye, or millet). Spawn production involves several steps, including selecting a pure culture of the desired mushroom species, inoculating the substrate with the culture, and allowing the mycelium to colonize the substrate.

To initiate spawn production, a small piece of mycelium from a pure culture is transferred to the sterilized grain substrate. The mycelium grows and spreads throughout the grains, creating a solid mass of colonized substrate called spawn. Spawn is usually stored in a controlled environment to maintain its viability until it is used for inoculating the growing substrate (Knop et al., 2015).

Inoculation and Incubation

Once the spawn is ready, it is used to inoculate the prepared substrate. This can be done through various methods, such as grain spawn, sawdust spawn, or liquid culture. Inoculation involves distributing the spawn evenly throughout the substrate to ensure uniform colonization.

After inoculation, the substrate is placed in a controlled environment with specific temperature and humidity conditions suitable for the mushroom species. This phase is known as incubation or spawning. During incubation, the mycelium grows and colonizes the substrate, breaking it down and absorbing nutrients. The length of the incubation period varies depending on the mushroom species and environmental conditions, but typically ranges from a few weeks to a couple of months (Singh and Singh, 2011).

Casing

For some mushroom species, a casing layer is added after incubation. Casing involves covering the colonized substrate with a layer of nutrient-rich material such as peat moss, vermiculite, or a mixture of various materials. The casing layer provides a microenvironment that promotes the formation of fruiting bodies (mushrooms).

Casing serves several purposes, including providing additional nutrients, regulating moisture levels, and promoting the initiation and development of mushrooms. It also acts as a protective layer against contaminants and helps maintain humidity around the developing fruiting bodies (Golak-Siwulska et al., 2018).

Fruiting and harvesting

After casing, the cultivation system is transferred to the fruiting environment. This environment typically has specific temperature, humidity, and lighting conditions that mimic the natural conditions required for mushroom formation. Fruiting triggers the development of mushrooms from the mycelium.

During the fruiting phase, mushrooms begin to form and grow from the casing layer. Proper humidity levels are maintained to prevent the mushrooms from drying out, while adequate ventilation ensures the removal of carbon dioxide and the replenishment of oxygen.

Identification of Genetic Variants and Improvement of Existing Strains

Techniques for genetic identification and fingerprinting are required for the characterization and improvement of Pleurotus strains. Molecular techniques have been utilized for the purposes of species identification, mating compatibility testing, and strain improvement (Urbanelli et al., 2007; He et al., 2017; Adeniyi et al., 2018). Some of these techniques include RAPD analysis, sequencing of the internal transcribed spacer (ITS), and AFLP analysis. These methods contribute to the commercial production of Pleurotus mushrooms by making it easier to choose disease-resistant and high-yielding variants of the fungus (Barh, 2019).

Genetic improvement plays a crucial role in enhancing the productivity, quality, and disease resistance of mushroom strains. Through the identification of genetic variants and the implementation of breeding programmes, researchers aim to develop improved mushroom strains with desirable traits. Let's explore the process of identifying genetic variants and improving existing strains in detail:

Genome Sequencing and Analysis

The first step in identifying genetic variants is to sequence and analyze the genome of the target mushroom species. Advances in DNA sequencing technologies have made it possible to obtain high-quality genome sequences, providing valuable insights into the genetic makeup of mushrooms.

Genome analysis involves identifying genes responsible for various traits such as yield, flavour, aroma, nutritional composition, and resistance to diseases. Comparative genomics studies also allow researchers to identify genetic variations among different strains and populations of mushrooms.

Marker-Assisted Selection (MAS)

Marker-assisted selection is a technique used to identify and select individuals with desirable traits based on genetic markers linked to those traits. Genetic markers are specific DNA sequences associated with particular traits or genes of interest.

By identifying markers associated with traits such as yield, disease resistance, or nutritional content, breeders can efficiently select individuals with those traits for further breeding programmes. MAS accelerates the breeding process by enabling the selection of desirable traits at an early stage without the need for time-consuming and resource-intensive phenotypic evaluation.

Breeding Programmes

Breeding programmes aim to combine desirable traits from different mushroom strains through controlled mating and selection. This involves crossing compatible strains to create hybrid progeny with improved characteristics.

Selective breeding is performed based on the identified genetic variants and markers associated with desirable traits. By selecting individuals with the desired genetic makeup and phenotypic performance, breeders can gradually improve the strains over successive generations.

Genetic Transformation

Genetic transformation involves the introduction of specific genes into a mushroom strain to confer new traits or enhance existing ones. This technique allows for the direct manipulation of the mushroom's genetic makeup.

Genetic transformation can be achieved through various methods, such as agrobacterium-mediated transformation, particle bombardment, or protoplast fusion. By introducing genes associated with traits such as increased yield, enhanced disease resistance, or improved nutritional content, researchers can develop genetically modified mushroom strains with improved characteristics.

Genomic Selection

Genomic selection is a relatively new approach that utilizes genomic information to predict the breeding value of individuals without the need for phenotypic evaluation. This technique combines the information from genome-wide markers with phenotypic data from a training population to develop predictive models.

Genomic selection enables breeders to select individuals with desirable traits at an early stage, accelerating the breeding process and reducing the time and resources required for phenotypic evaluation. It also allows for the simultaneous improvement of multiple traits by considering their genomic associations.

Methods of Farming That Are Friendly to the Environment

By using waste products from agriculture as substrates, the cultivation of Pleurotus mushrooms represents an environmentally responsible method of farming (Adebayo and Martínez-Carrera 2015). They have the ability to transform lignocellulosic wastes into food sources that are nutritious and useful, thereby decreasing waste and encouraging the concepts of circular economies (Patil et al., 2010). Indigenous mushroom growing approaches, which make use of regional resources and traditional mushroom cultivating expertise, have also been investigated (Wendiro et al., 2019). These methods not only contribute to the safety of the food supply but also support the sustainability of the ecosystem.

Conclusion

The nutritional prowess and potential health advantages offered by Pleurotus mushrooms, also known as oyster mushrooms, present a captivating avenue for both the food industry and the realm of human health. These remarkable fungi can be cultivated using an array of lignocellulosic materials and agricultural waste products, showcasing their versatility and sustainability.

The nutritional profile of Pleurotus mushrooms is impressive, boasting a rich composition of essential nutrients such as proteins, dietary fibre, vitamins, and minerals. With their low-calorie and low-fat nature, these mushrooms make for a wholesome addition to a balanced diet. Notably, Pleurotus mushrooms stand out as a superior plant-based protein source, providing all the essential amino acids required for protein synthesis in the body.

Moreover, the dietary fibre content of Pleurotus mushrooms contributes to their health benefits by aiding in digestion, promoting satiety, and supporting proper bowel movements. These mushrooms also harbour an assortment of bioactive compounds, including polysaccharides, beta-glucans, phenolic compounds, and antioxidants, which have been linked to immune-enhancing properties and potential protection against chronic diseases.

The cultivation of Pleurotus mushrooms on lignocellulosic materials and agro-waste products serves as an ecologically sound and economically viable solution. By utilizing substrates such as straw, sawdust, and agricultural residues, these mushrooms not only contribute to waste management but also demonstrate an environmentally friendly approach to recycling and repurposing agricultural by-products.

In essence, Pleurotus mushrooms embody a paradigm shift in food production with their exceptional nutritional content and health-promoting properties. Incorporating these mushrooms into our diets can enrich our culinary experiences while providing an array of health benefits. Nonetheless, further research is warranted to delve deeper into the bioactive compounds present in Pleurotus mushrooms and unravel their intricate mechanisms of action in supporting human health.

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Technological advancements in fodder production: a review

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Abstract

Livestock is a sub-sector of agriculture that plays an important role not only in the Indian economy but also in national nutritional security, particularly for small and marginal farmers. But the production potential of our animals is not comparable with that of the global average due to many reasons, feed and fodder deficiency being the major one. The feed shortage in India is due to the unavailability of land for quality fodder cultivation. Thus, there is a burning need to adopt innovative methods not only in production but also in the preservation of fodder. Unconventional methods in fodder production, including seed technology, system approaches, hi-tech farming and adopting mechanization in fodder production, can be considered for their advancement. Being the leader in cattle and buffalo populations and increasing livestock populations, current fodder production in our country is not able to meet the requirement. Improved technology in fodder preservation, including technical interventions in hay and silage like supplementation with additives for quality hay and silage, preserving as haylage and balage and making dehydrated products like pellets and cubes, can also be considered for increasing quality fodder production and utilization. Land under fodder cultivation is static and has little scope for expansion due to reduced per capita availability and human priorities. So, technological advancements both in the production and preservation of fodder should essentially be adopted to fight against fodder scarcity.

Keywords: BN hybrid, Dinanath grass, Guinea grass, hitech farming, system approach.

Introduction

India is fundamentally an agricultural country, with about two-thirds of the rural population directly depending on it for their livelihood. India has vast livestock resources, including poultry. Livestock is an important source of income for landless and marginal farmers and plays an important role in the national economy. Animal husbandry and dairying activities, along with agriculture, have continued to be integral parts of human life since the process of civilization started. According to the first revised estimates of the press note on "First Revised Estimates of National Income, Consumption Expenditure and Capital Formation for 2020-21" released by the National Statistical Office (NSO) and MoSPI on January 31, 2022, the gross value added (GVA) of the livestock sector is more than INR 11.14 billion at current prices during FY 2020-21, which is about 30.9%

of Agricultural and Allied Sector GVA and 6.2% of Total GVA (GOI, 2022). Livestock plays an important role in nutritional security, particularly for small and marginal farmers. The productivity of livestock in India is lower than the global average. The main reasons for it may be considered improper nutrition, inadequate health care, and management. The improper livestock nutrition reflects the unavailability of cultivable land for fodder production due to the priority of human nutrition. Being the leader in cattle and buffalo populations, the livestock population is increasing every year at a rate of 4.82% from 2012–19 (GOI, 2021). The current fodder production in the country is not meeting the requirements of the animals. The country has a deficit of 63.5% green fodder and 23.5% dry crop residues. If the present scenario continues, the discrepancy will increase to 65.5% by 2030 (ICAR-IGFRI, 2015).

Shortcomings in fodder production

The main constraints of fodder cultivation include the unavailability of land for fodder production, more labour needs, more growth time (approximately 45–60 days), the nonavailability of constant fodder quality round the year, uncertain rainfall, the requirement of manures and fertilizers and the insufficiency of water (Naik et al., 2015). The non-commercial status of forages and an unorganized small market without any government policy support like a minimum support price make fodder production a low-priority crop. As a result of the animal feed deficiency and unavailability of land for fodder cultivation, it is a burning need for the nation to adopt advanced technologies in fodder cultivation, both in production and preservation of fodder. The increased cost of packaged cattle feed adds to the cost of production in the dairy sector.

Advanced techniques in fodder production

Advanced techniques in fodder production can be considered in four aspects: seed technology, system approach, hi-tech farming and mechanization (Thomas and Thomas, 2019).

Seed technology

Only about one fourth to one third of the required quantity of quality seeds for cultivated fodder is available in India, which is capable of covering less than one tenth of the required area of range grasses and legumes. Thus, there is a need to evolve superior varieties of forage crops with high yield and quality and also develop new technologies for multiplication.

Planting material multiplication in the Bajra-Napier hybrid

Bajra-Napier hybrid (BNH) is an imperative perennial fodder that yields up to 250 t ha^{-1} of green fodder under irrigated conditions. As there is no seed formation in this interspecific hybrid, vegetative propagation is the only option for BNH cultivation. But multiplication and sale of planting material have major constraints: for example, high transportation costs, damage to the standing crop from where rooted slips are taken out and high labour costs.

In-vitro rooting in the Bajra Napier hybrid

A packing-friendly technique for BNH-rooted slips has been developed using suitable aged stem cuttings with 2-3 nodes and wrapping them in a specific material like paper or cloth. Keeping these wrapped cuttings at 25ºC and 80% humidity is safe for one week, and rooted slips can be produced from this bioplasm. The process reduces the difficulty of uprooting the material in the field and helps with easy transport over long distances. This technology is mainly convenient for clients with small requirements who need appropriate conveyance facilities for long distances. The *in-vitro* rooting of BNH helps in the production of rooted slips within a short span of one week. As the rooted slips produced in the laboratory are already packed in suitable bundles, it is very easy to transport them from one place to another over a long distance without much drying or damage (Vijay et al., 2018).

High-density nursery in the Bajra-Napier hybrid

The stem or tillers from BNH may be collected and chopped into pieces of one, two, or three nodes called setts. A slant basal cut may be given to increase the area of contact during planting in the field. The sets are closely planted in an upright position with at least one node inside the soil at a 5 cm row-to-row and 5 cm plant-to-plant distance. The shoot buds start transforming into leafy shoots within 10 days and roots emerge after 15 days. The sets are ready for transplanting in 4 to 5 weeks with proper root and shoot. Original tussocks may be saved (Vijay et al., 2018).

In-vitro maturation of Guinea grass seeds

Among many perennial grasses, Guinea grass (*Panicum maximum*) is well adopted by Indian farmers. The reason is its multi-cut nature and high green fodder yield, reaching up to 80 to 100 t ha^{-1}. The seed maturity in this crop varies from plant to plant and branch to branch. Mostly different stages within an inflorescence, starting from anthesis to seed ripening, are observed. This makes it difficult to realize the full potential of seed production. The manually harvested seeds are characterized by a germination potential of only 15–30%. To overcome this limitation, *in vitro* maturation of guinea grass is done. The panicles are cut before the anthesis stage and dipped in suitable hormonal solutions like 100 ppm indole acetic acid to retain their viability for a longer duration, which thus helps in proper seed maturation. By using this *in vitro* procedure, the seed shedding in guinea grass may be diminished and the collected seed may be more homogeneously mature, resulting in improved seed filling. This technology helps the production of high-quality seed with reduced production losses and benefits the farmers by having a high germination percentage with superior chances of seedling establishment (Vijay et al., 2018).

De-fluffing of Dinanath seeds

Amongst annual range grasses, Dinanath (*Pennisetum pedicellatum*) is an important fodder crop, having high early vigour and adaptability to very poor soils (Kishore and Verma, 2000). The fodder yield potential of this perineal fodder is higher compared to sorghum with minimal inputs (Kishore and Singh, 2021). The feeding value of this forage has also been compared with that of sweet sorghum (Sharma and Kishore, 2022). The crop is a producer of a large number of seeds; however, the small seed, with its light weight enclosed in voluminous fluff leads, makes it difficult to transport as well as precise sowing in the field. Reducing the volume of the huge fluff and extracting true seed for precise sowing is the need of the day for large-scale, successful usage of Dinanath grass. The naked caryopsis from Dinanath seed fluff may be detached from the fluff using a cotton batting machine with minor alterations. Thus, the true seed occupies a much smaller volume and the weight is reduced from 7 kg to 450 g. This technique reduces the difficulty of transportation and sowing Dinanath grass to a great extent.

This technology is a boon to grass seed producers and farmers, as it reduces the volume of seed and improves the ease of carrying it over long distances. The de-fluffing process also benefits by providing the naked seed for pelleting (Vijay et al., 2018).

Modified method for seed pelleting in Dinanath

Dinanth grass seeds are very small and full of fluff or appendages. They are easily blown off and are supposed to sustain mechanical damage at a higher rate. Grass seed pelleting has long been thought to be a solution for addressing this issue. An experiment was conducted at the Indian Grassland and Fodder Research Institute (IGFRI), Jhansi, to pellet Dinanath grass in a specially fabricated tyre-based machine. Seed pelleting involved mixing fluffed seeds of this grass, soil and water at an appropriate ratio in a rotating tyre to make seed balls of 15–20 mm diameter. Six types of locally available pelleting materials, viz., soil, sawdust, wheat bran, charcoal, farmyard manure and limestone, were tried at the initial stage to make seed balls. An exact quantity of pelleting material was put in the rotating tyre, followed by a water spray onto the dry mix until it began to nucleate and form small beads. When the beads reached approximately one cm in diameter, the desired quantity of seeds was dusted slowly on the rotating beads. The seeds adhered to the bead’s surface were given a water spray, followed by dusting with pelleting material to cover the seeds by making a pelleting layer. The pelleting has many advantages, like increasing germination potential to more than 90%, enhancing seed field performance, helping in mechanization and improving vigour as it is supplied with nutrients and water absorbents (Maity et al., 2015).

System approach

In most parts of the country, it is common to observe farming systems integrated with forage crops and livestock production. Undoubtedly, it is the best alternative to increasing the area and production of forage crops, as there are constraints to bringing more land under forage crops (Thomas, 2003). Some of the prominent farming systems with forage crops practiced in the tropics, namely intercropping, sequential cropping and agroforestry, may be useful (Thomas and Thomas, 2019).

Intercropping

Dominant multiple-cropping systems have been practiced in the tropics. The main objective of this technique is to utilize the space between the main crops and produce additional yield. Important fodder crops suitable for intercropping are guinea grass, hybrid Napier, cowpea, congo, signal and gamba grass.

Sequential cropping

A system of growing two or more crops in the same field per year, one after the other, is called sequential cropping. A very common example of sequential cropping is growing fodder in summer rice fallows.

Agroforestry

Any land use system that includes both trees and agricultural crops on the same piece of land It is divided into subsystems, including the silvicultural system, the agri-silvicultural system, the silvi-pastoral system and the agri-silvi-pastoral system.

Silvi-pastoral system

A Silvi-pastoral system is a land management system involving trees and grasses. Mostly, the silvi-pastoral combinations are based on fodder trees or shrubs. The major well-known fodder trees are subabul, glyricidia, calliandra, agathi and hedge lucerne, whereas the major well-known fodder grasses are guinea grass, hybrid napier and congo signal. A study was conducted at IGFRI to evaluate the forage production of grasses and legumes in various combinations with fodder trees. Among the fodder crops, *Chrysopogonfulvus*, *Panicum maximum*, *Cenchrusciliaris and Stylosanthes seabrana* intercropped with the fodder trees *Ficus infectoria*, *Madhucalatifolia*, *Morus alba* and *Acacia nilotica green.* The combinations with *Panicum maximum* proved their seniority compared with others in terms of forage production (ICAR-IGFRI, 2018).

Hi-tech farming

In addition to conventional farming methods, certain advanced, hi-tech farming techniques are adopted in fodder production. The major hi-tech farming methods adopted are fertigation, vertical farming, fodder on terraces and hydroponics (Thomas and Thomas, 2019).

Fertigation

Fertigation is a technique of fertilizer application with irrigation. In fertigation, fertilizer is added to the irrigation water in the drip system. The application of nutrients to forages is negligible. But studies have shown that there is a substantial increase in fodder yield when fertilizers are added to the irrigation water, the maximum being when applied through the drip technique. Hassan et al. (2010) carried out experiments to test the impact of varying nitrogen levels from 0 to 180 kg ha^{-1} applied through different application methods, viz., broadcast, fertigation and side dressing, on fodder maize. Nitrogen fertigation proved to have better efficiency than broadcast and side dressing. Maximum leaves/plant, stem girth, green fodder yield, total dry matter, leaf area index, leaf area duration, N content and N uptake were recorded with the application of 140 kg N ha^{-1} through fertigation.

Vertical farming

Vertical farming is the specific practice of growing crops in vertical layers. The major objective of vertical farming is to produce crops in challenging, adverse environments; for example, arable land is rare or unavailable. Growables in irrigated grow bags, goats integrated for nutritional security with fowl, azolla, rabbit management vertically and intensively in limited land available (GIGGINS FARM VILLA) is an intensively integrated vertical farming system developed by the Kannur division of Krishi Vigyan Kendra (KVK) with the aim of convergence of agriculture, animal husbandry, and dairy farming. The system helps farmers overcome constraints posed by a lack of space. The unit can be set up on even one cent of land. Multifaceted nature makes it attractive wherein farmers can rear goats, hens, rabbits and quails while also cultivating vegetables, producing seeds, supplying saplings and catering to the production of organic manure. In short, it is a comprehensive unit of farming that assures guaranteed income for families.

It is structured like a pyramid and made of two galleries supporting each other to form the roof of the double-storied animal house. In GIGGINS FARM VILLA, the ground floor is used for poultry farming and the first floor for goats. Rabbits are accommodated in hanging cages, whereas azolla is grown in tanks over rabbit cages. Galleries accommodate bags with microirrigation to grow fodder for animals. The structure is 16 ft in height, 32 ft in length and 10 ft in width, with a floor area of 384 ft^2. It gives an effective utility area of 44 sq ft (Giggin, 2015).

Growing fodder on the terrace

Scientists from the KVK, Kannur, have developed an advanced technique to grow fodder grass on the roof tops of cattle sheds to help dairy farmers solve space constraints and fodder scarcity. The technique, called high density double planting with drip irrigation, involves growing fodder grasses in plastic 'grow bags," usually used for vegetable cultivation. The grasses grow to a height of six to eight feet in a span of two months. The fodder grasses are cultivated in stabilized bags, placed equidistantly, with a foot's space left between the bags. Water and fertilizers are supplied using drip irrigation. The first harvest can be done after 10 weeks of planting and thereafter every 30 days. Different varieties of grass can be grown using this technique. This advancement is attractive because of the additional financial gain for the farmers. A cow, which is usually given concentrate feed costing INR 22 per kg, can easily be given five kg of green grass at INR 5 per kg. Such a huge saving in production costs may be a boon for the dairy sector. Apart from growing forage crops, the producers can also go in for selling the root slips of the green grasses, which can give them an additional handsome income. A single root costs INR 2 and there is quite a demand for procuring fresh green grass. An investment of INR 100 a month produces fodder costing INR 6,000 in six months. Grass grows faster with this technique because of the ample sunlight available. Moreover, the nagging problems of pests and weeds are almost absent. A single bag has a life expectancy of three years.

Hydroponics

To overcome the constraints of area in forage production, hydroponics is now emerging as an alternative technology to grow fodder for farm animals. Fodder produced by growing plants in water or a nutrient-rich solution without using any soil is called hydroponics fodder, sprouted grains, or sprouted fodder (Dung et al., 2010).

Hydroponics techniques have proven beneficial and efficient for producing food for animals. Fodder is grown year-round under controlled climatic conditions and is rich in minerals, proteins, amino acids and vital nutrients. The forage is free of diseases, residues of pesticides or chemicals and organic in nature. It improves the health, productivity, fertility and longevity of the livestock and saves land, water and labour (Khanna, 2014). Sneath and McIntosh (2003) reported that grain sprouts are not only highly digestible but also nutritious feeds. The energy in grain is largely starch and while sprouting, the grains convert much of the starch to sugars. The sprouting of grain also increases fibre levels. Khanna (2015) concluded that replacing farm-made concentrate mixtures with hydroponic maize fodder resulted in improved digestibility of gross nutrients (except dry matter and organic matter) and fibre fractions.

There are numerous grains that can grow in hydroponics. Grain crops like oats, barley, wheat, sorghum and corn have been cultivated hydroponically. When choosing a grain, the main characteristics that come into play are its nutritional value, speed of grain growth and protein levels. Naik et al. (2015) suggested maize may be used for the production of hydroponic fodder due to its easy availability, lower cost, good biomass production and quick growing habit. In comparison to conventional green fodders, hydroponic green fodders contain more protein, ether extract and nitrogen-free extract but less fibre, total ash and acid-insoluble ash. Naik et al. (2012) compared the chemical composition of conventional fodder maize and fodder maize grown in hydroponics systems and reported that there was a considerable increase in crude protein, nitrogen-free extract and ether extract in maize grown in hydroponics systems compared with conventional.

Jolad (2018) experimented to evaluate suitable crops for hydroponics. Twelve crops, including fodder and grain maize and barley, wheat, oats, fodder cowpea, grain cowpea, horse gram, soybean and lucerne, were taken for the study. The fodder maize produced the maximum seed yield of green fodder. It was almost similar to grain maize, grain cowpea and horse gram.

Mechanized farming

Fodder production requires intensive labour during processing and utilisation, a time-consuming and energy-intensive operation. The emphasis is given that variable costs can be reduced by good mechanization planning, which leads to more profitable fodder production with the effective use of agricultural machinery (Türer and Yildiz, 2023). Optimal production and utilization of forage crops require minimal, critical and timely operation. Delay in forage production operations usually causes loss of moisture and thus deteriorates fodder quality. There are some specialized mechanization requirements for fodder. Many cultivated fodder crops are multi-cut and produce volumes of green and dry matter during the time of harvest. Large volumes and mass handling require suitable machinery. Major farming communities fall under small land holdings (1-3 ha field size). A small farmer, usually possessing 2–10 animals, assigns a small portion (up to 10 per cent) of his cultivated land to fodder cultivation. Accordingly, mechanization is required to fulfil their needs (Sahay et al., 2016).

Non-conventional fodder resources for livestock feeding

During periods of scarcity of feed and fodder for livestock, there is a need to consider the available alternatives to the common feed and fodder resources to cope with the daily needs of the livestock. Azolla (*Azolla sp*.), a fern, has been reported to be a very good source of protein, essential mineral elements and vitamins for livestock. Among the several species of Azolla, *Azolla microphylla* has been found to be best suited for dairy animal feeding in tropical zones. The fresh yield of azolla was around 200–250 g m^{-2} day^{-1} (Singh, 2016). Cactus, a member of the plant family Cactaceae, has flat oval stems known as cladodes or paddles that remain green and succulent throughout the year and contain on average 90% moisture. As a dairy animal feed, cactus can be used as a substitute. A large quantity of green fodder from cacti throughout the year can be produced if managed properly. It is also capable of providing sufficient amounts of water, energy and vitamins during the panic period of the dry seasons. Opuntia have spineless types and spiny types, but both have similar feeding values. The spiny-type cacti, however, pose certain utilization issues due to the physical damage to the alimentary tract of the grazing animal. Therefore, spines are required to be removed by burning or scraping before feeding them to animals. Opuntia contains low levels of fibre and protein; hence, it needs to be supplemented with fibre and nitrogen-rich sources to meet nutritional requirements and enhance animal performance. All the cacti are drought-tolerant and make use of little moisture in rainy seasons to produce large quantities of green forage. The cactus has a high carrying capacity compared to any other drought-tolerant forage in arid or semi-arid zones. The cacti have not only drought tolerance but high water use efficiency as well; hence, they are in a position to produce large quantities of forage that remains green and succulent for long periods of drought. The cacti are easy and cheap to establish. All of these properties make it the best fodder option in changing climatic situations, especially in arid and semi-arid zones (Singh, 2016).

Advanced techniques in fodder preservation

Forage conservation is a key element for productive and efficient livestock farms. Forage conservation permits a better source of quality feed resources when forage production is low or dormant. Forage conservation also offers farmers a means of preserving forage when production is higher and faster compared to requirements. Additionally, the preservation of fodder prevents lush growth from becoming too mature. Consequently, forage conservation provides a more uniform level of high-quality forage for livestock throughout the year (Muck and Shinners, 2001). Forages are preserved as either hay or silage. During hay production, the plants are dried to 15 per cent dry matter (DM) content to make them biologically inactive with respect to plant enzyme activities and microbial spoilage. The low moisture content also permits easier transportation by reducing the weight per unit of DM. The making of hay is leading in areas of the world where good natural drying conditions are present. Hay is also very common in humid climates where ensiling has been considered too difficult because of forage characteristics, high temperatures, or tradition. Normally, haymaking is completed by the traditional sun-curing method, but in some areas, the mechanical drier method is also in use (Thomas, 2003). In silage making, or ensiling, anaerobic fermentation of green fodder in specific structures called silos takes place. It is commonly called pickles of green fodder for the dairy animals (Borreani et al., 2018). Advanced techniques in preservation include technological interventions in hay and silage, additives for quality hay and silage, haylage, balage, dehydrated products, pellets and cubes (Thomas and Thomas, 2019).

Additives for quality hay and silage

Preservatives are added to silage. The major preservatives may be enlisted as sodium metabisulfite, which helps in partial sterilization and checks bacterial growth; salt, which makes silage more palatable and improves fermentation; and non-protein nitrogen, ammonia, and urea, which are added. It decreases the growth of yeast and molds and propionates *from Propionibacterium* spp. are added, which reduce plant respiration and heating (Kaiser, 1999). The biopreservatives may be enlisted as bacterial inoculants and include *Lactobacillus, Pedicoccus and Streptococcus*. It increases lactic acid bacteria, decreases DM and protein degradation losses and sugars (molasses, glucose and dextrose) are usually added. It increases lactic acid content by providing more sugar for bacteria (Muck and Shinners, 2001). Based on a study conducted to assess the harvesting intervals and additives for quality silage production, it was found (Ishrath, 2016) that quality silage can be prepared by ensiling the hybrid Napier harvested at a 45-day interval and fortifying it with 2% urea or 1% urea + 1% jaggery as additives. The mixing of corn-cowpea or oats-alfalfa at a ratio of

75:25 proves an effective way to make quality silage, ensuring the supply of nutritionally rich silage throughout the year (Goyal and Tiwana, 2016).

Silage

The terms haylage and silage are often confused and used interchangeably. Silage is defined as "material produced by the controlled fermentation of a yield with a high moisture content" (McDonald et al., 1991). The forage nutrient contents and sward structure have different influences on the intake of dry matter, average daily gain and methane emissions by grazing ruminants (da Cunha et al., 2023). The ensiled forages show little potential to reduce enteric methane emissions when fed to growing beef cattle (Meo-Filho et al., 2023). The ensiling is based on the transformation of water-soluble carbohydrates, which must be transformed into at least 10% of the dry matter in lactic acid. This favourable condition is an anaerobic environment, created by the work of anaerobic lactic acid bacteria and other microorganisms, with adequate moisture (65-70% in forages and 33–38% in the concentrated feed) and temperature (35–380°C). The silage quality was satisfactory, with moisture content ranging between 51.5 and 52.5% and crude protein between 4.8 and 5.6% (Jugovic et al., 2014).

Haylage

Haylage is also called hay crop silage, low moisture silage, or drylage. It contains 40–60% moisture. Important aspects to be considered while making haylage include wilting, dry matter content, chopping, and the exclusion of air. The process has many advantages over hay and silage; for example, storage losses are reduced, weather-associated risks are low and palatable feed is liked by animals devoid of objectionable odours. Haylage can be made successfully in conventional silo structures. Large plastic bags are also becoming popular among dairy farmers for haylage storage. Haylage is wrapped or anaerobically stored feed containing more than 500 g DM kg^{-1} (Müller 2005; Harris et al., 2017). Chemical analysis of haylage samples is reported to be moisture 51.46 and 52.45%, ash 3.30 and 4.69%, crude cellulose 17.82 and 18.48%, crude protein 4.82 and 5.57%, crude fat 1.21 and 1.32%, NFE 21.39 and 17.13% and energy value 429.65 and 457.69 KJ/100g, made in silo-trenches and wrapped bales, respectively (Jugovic et al., 2014). The influence of sowing time on the nutritional value of haylage from annual grasses has been studied. The crude protein and metabolizable energy transformations are at a higher rate in the crops sown early, followed by mid- and late-season (Kondratenko et al., 2021).

Multi-species haylages are more productive and stable than single-species ones and provide a well-balanced, nutritious food (Artemiev, 2010; Merzlikina, 2010; Khramoj et al., 2019). The limiting factors in multi-species haylage are decreased to result in an increase in animal productivity (Mironova et al., 2019). The nutritional value of haylage obtained from the green mass of cereals and legumes is very high. (Karamaev et al., 2019).

Balage

Balage, also called "round-bale silage," is baled fodder at a higher moisture content and then stored in sealed plastic wrap. A high moisture level and an airtight environment are needed for a male perfect fodder bale (Borowski et al., 2021). Balage is a fermented product preserved by acids. Storing silage in round bales is a commonly used method for preserving forage for use as stock fodder, which has a higher nutritional content than hay. In the case of the balage, good density ensures ideal conditions for fermentation (Jamroz et al., 2001; Han et al., 2006; Nowak, 2013). The moisture content of the plant material has a big impact on the compacting process. Humid blades or stalks bend fodder much more easily than dry ones. Attention is given during the compaction of bales formed from green forages with a DM content of 63 to 64 per cent. This material has low elasticity and is easily pressed into the working chamber of a round baler, resulting in a high concentration within the cylindrical bales (Coblentz and Hoffman, 2009). The addition of shredding assemblies to the round balers produces bales of high concentration (Charmley and Firth, 2004; Lötjönen, 2008). The production of feed with the use of different additives to support the silage and balage making processes is very popular because of the cheaper supplies of valuable feed with low nutrient losses that are suitable for long-term storage (Dulcet and Woropay, 2000; McEniry et al., 2006; Doroszewski, 2009; Muck, 2012). Liquid feed additives are applied to the plant material by applicators fitted to a baler. Applicator nozzles are mounted on the baler at points to allow for optimum distribution of liquid feed additives in the collected plant material and low additive losses (Dulcet et al., 2006; Nysand and Suokanns, 2012; Wyss et al., 2012).

Dehydrated products

The dehydration of fodders is due to their agronomic potential. The dehydrating industries are using dehydrators to meet the requirements of the dried fodder markets. In Spain, lucerne, raygrass, fescue and forage corn are very common causes of dehydration (Marrugat, 2001). Artificially dried chopped forage can be made dense for storage by compressing it into wafers or cubes extruded from a ram press or rotary die press, respectively. It may be milled or pelleted. Pellets and cubes are the most common dehydrated products in India (Bakshi et al., 2018). Alfalfa pellets are now widely available in local markets. A power-operated feed pelleting machine was developed by IGFRI to produce value-added feed pellets. It includes azolla-added feed pellets (groundnut cake was replaced with dried azolla leaves) and value addition through berseem and moringa leaves (chopped and dried berseem was added in place of Leucaena leaf). Dried moringa (*Moringa oleifera*) leaves are very successful in preparing firm pellets (ICAR-IGFRI, 2018).

Conclusion

Being the leader in cattle and buffalo populations and increasing livestock populations, current fodder production in our country is not able to meet the requirement. Land under fodder cultivation is static and has little scope for expansion due to reduce per capita availability and human priorities. So, technological advancements both in the production and preservation of fodder should essentially be adopted to fight against fodder scarcity.

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Pharmacological and nutritional benefits of mushrooms

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Abstract

Mushrooms are the valuable food source with diverse nutritional and medicinal properties. This review highlights their potential as a rich source of bioactive compounds and explores their pharmacological effects. Mushrooms exhibit anti-cancer, anti-bacterial, anti-oxidative, anti-viral, anti-diabetic, and anti-allergic properties. They contain essential nutrients, including proteins, vitamins, minerals, and nutraceuticals. Different types of mushrooms possess unique compositions and medicinal properties. The bioactive compounds found in mushrooms, such as triterpenes, polysaccharides, and amino acids, contribute to their pharmacological activities. Mushrooms are a source of macronutrients, B-complex vitamins, vitamin D, and minerals, and they demonstrate various biological activities, including anti-inflammatory and neuroprotective effects. Understanding the nutritional and pharmacological value of mushrooms can drive their application in functional foods and therapeutic interventions, benefiting urban as well as rural individuals with degenerative and metabolic diseases.

Keywords: Health, Nutritional composition, Oyster mushroom, Pharmacological properties.

Introduction

Mushrooms are edible fungi consumed as delicacies in various parts of the world. They are rich in various nutrients and have various pharmacological effects in humans, yet their significant importance is not well known to everyone. Mushrooms are eaten all over the world due to their distinctive taste and flavour. Mushrooms have extraordinary potential due to their bioactive secondary metabolites and there is a huge potential for using them as drugs. Their pharmacological properties include anti-cancer, anti-bacterial, anti-oxidative, anti-viral, anti-diabetic and anti-allergic properties. Mushrooms are now used in different countries for the treatment of various types of cancer, diabetes, hypertension, inflammation and many other diseases. They contain nutrients like vitamin B-complex, zinc, selenium, protein, pantothenic acid, copper, potassium, glycerol, mannitol, beta-glucans, phosphorus, polysaccharides, magnesium, etc. The nutritional composition of mushrooms accounts for 50–65% on a dry weight basis. The sugars present include different monosaccharides and oligosaccharides. Various alcoholic sugars like mannitol and trehalose are also present in mushrooms. The protein content of mushrooms varies from 19–35%, and the fat content varies from 2–6% on a dry matter basis. The mushroom contains polyunsaturated fatty acids such as palmitic acid, oleic acid and linoleic acid. Mushrooms are rich in vitamin D and are thought to be the only vegetarian source of vitamin D. Edible mushrooms could be a source of many different nutraceuticals, such as unsaturated fatty acids, phenolic compounds, tocopherols, ascorbic acid and carotenoids. They contain various minerals that are required by our body. Studies have shown their influential effects against malignancy (cancer), cholesterol decrease, stress, sleeping disorders, asthma, etc. The high content of protein present in mushrooms can be used to prevent clinical and subclinical symptoms of protein deficiencies. Their low carbohydrate and cholesterol content make them suitable for consumption by diabetics as well as patients with cardiovascular disease. The mushrooms were used in ethno-medicines or traditional medicines as they have remarkable potential for curing various health diseases (Devishree et al., 2017). The biochemical compounds present in mushrooms play an important role in contributing to the various pharmacological roles of mushrooms. The biochemical compounds present in mushrooms include triterpenes, polysaccharides, germanium, adenosine, ganoderic quintessence, amino acids, nutrients, minerals, beta-glucan, heteroglycan, proteoglycan, and nucleotides. The various types of mushrooms include:

- Button mushroom
- Hedgehog mushroom
- Cremini mushroom
- Portobello mushroom
- Maitake mushroom
- Morel mushroom
- Shiitake mushroom
- Porcini mushroom
- Lobster mushroom
- Enoki mushroom
- Clamshell mushroom

Mushrooms contain a wide number of minerals and minor components like potassium and copper as well as nutrients like riboflavin, niacin, and folate. Mushrooms are low in energy and fat yet high in protein and dietary fibre. Bioactive metabolites such as phenolic compounds, sterols and triterpenes are also present in mushrooms (Souilem et al., 2017). Mushrooms are a treasure trove of food that plays an immense role in curing various degenerative and metabolic diseases.

Nutritional properties of mushrooms

Macronutrients

Mushrooms are rich in proteins, with digestibility as high as 75-82%. The protein content of mushrooms depends on their variety, size and harvest time. It basically contains protein ranging from 19–35%, which is higher as compared to convenience food crops like rice, corn and wheat. The quality of protein is also high, as it contains all the essential amino acids required by the body (Malinowski et al., 2021). The carbohydrate content present in mushrooms is about 50–65% on a dry matter basis. Water-soluble carbohydrates have pharmacological effects in the body. The fat content in mushrooms ranges from 2–6%, which includes the essential fatty acids.

Vitamins

Mushrooms are rich sources of fat and water-soluble vitamins (Valverde et al., 2015). Mushrooms are rich in B-complex vitamins like thiamine, cyanocobalamine, riboflavin, pyridoxine, niacin, and pantothenic acid. These vitamins act as coenzymes, facilitating the various metabolic reactions occurring inside the body. Mushrooms also have a higher content of vitamin D. Ascorbic acid is also present in mushrooms in small amounts. Provitamin A and vitamin E are also present in mushrooms.

Minerals

Mushrooms have major minerals like K, P, Na, Ca, Mg, etc., which constitute about 50–76% of the total ash content of the mushrooms (Kalac et al., 2000). Wild mushrooms have a higher mineral content than cultivated ones. Zinc, selenium, copper, iron, etc. are also present in mushrooms. Selenium and zinc have antioxidant potential and can help prevent oxidative damage. Zinc plays the most important role in allowing the body's defensive (immune) machine to nicely work and it also helps in cell division, cell development and wound healing. Copper helps in the production of erythrocytes, which are used to supply oxygen all around the body. Selenium works as an antioxidant to shield our body cells from harm that could possibly result in coronary heart disease and also prevent ageing. The potassium-to-sodium ratio in mushrooms is higher, i.e., 110:1, which is helpful in improving blood circulation and also prevents high blood pressure.

Biologically active compounds

Mushrooms contain the aromatase enzyme, which is important for the production of oestrogen in the body. Various alkaloids like cordycepin, lectins, levostatin, etc. are beneficial for various functions in the body. The mushroom sterol (ergosterol) performs the same function as cholesterol. Antioxidants present in mushrooms include a compound called ergothioneine, which has protective functions against CVDs, chronic inflammation, and neurodegenerative diseases (Rathore et al., 2017).

Pharmacological properties of mushrooms

Anticancer properties of mushrooms

The bioactive metabolites play an important role in the anticancer properties of mushrooms (Sarma et al., 2018). One of the mushrooms, named Tiger Milk Mushroom, contains a high level of beta-glucans, which play an important function in boosting the immune system of the body and also prevent cancer-forming cells from spreading. Moonshine mushrooms contain different bioactive compounds such as polysaccharides, polysaccharides-protein edifices, and beta-glucan, which exhibit mitigating, cancer prevention agent, hostile to proliferative and immuno-adjusting impacts. In ancient times, the powder of reishi mushrooms was utilized to cure cancer in China. It was used for performing chemotherapy in cancer patients and it was found to be beneficial to decrease tumour and malignant cell growth in patients with breast and prostate cancers. Various RCT investigations uncovered the role of polysaccharide K (PSK) from mushrooms in standard chemotherapy, which expanded the endurance of patients after healing gastric malignancy resection over chemotherapy alone. It confirms the capacity of polysaccharides to incite apoptosis and different types of disease cell death through immunological components present in the mushrooms. The cancer-preventing action of mushrooms can be correlated to the phenolic components of mushrooms, such as flavones, flavonoids, etc., which have anti-cancer potential.

Anti-oxidant properties

Oxidation of any compound in human cells results in the formation of free radicals. These free radicals, through a series of reactions, are responsible for the oxidative damage of the cells, leading to cell death and tissue injury. Bioactive compounds like natural antioxidants are responsible for ending this chain reaction and preventing oxidative damage to the cells. The mushrooms are rich in compounds like selenium, polysaccharides, rufoolivacin C&D and leucorufoolivacin, phenolic compounds, etc., which act as antioxidants and prevent oxidative damage to cells. These antioxidants stop the chain reactions of free radicals like hydroxyl, peroxide and DPPH radicals. The polysaccharide-peptide complex LB-1b present in mushrooms also exhibits antioxidant activities (Egra et al., 2019) and prevents the hemolysis of erythrocytes. Polysaccharide and phenolic compounds are responsible for enhancing the activities of antioxidant enzymes present in the liver, heart and other organs. Polyphenols are also involved in metal chelation and prevent LDL oxidation, which can be correlated to the prevention of various heart diseases (Mohamad et al., 2017).

Anti-bacterial properties

Mushrooms like oyster mushrooms have polysaccharides that hinder the growth and reproduction of bacteria like *Bacillus subtilis* and *Streptococcus epidermidis* (Gashaw et al., 2020). The brown oyster mushroom can inhibit the growth of various strains of bacteria. Reishi mushrooms also have antibacterial effects (Vazirian et al., 2014). The mushrooms are considered one of the richest sources of natural antibiotics to prevent the growth of microorganisms. Various isopyrocalciferol acetates, triterpenoids and ergostrol present in mushrooms have inhibitory effects on gram-positive bacteria and yeast.

Anti-inflammatory properties

Inflammation is a natural response of the immune system of the body to various physical, chemical, or pathogenic factors. This may be due to deficiencies in antioxidants and anti-inflammatory agents like zinc, selenium, etc. Mushrooms are enriched with anti-inflammatory elements like polysaccharides, phenolic and indolic compounds, myco-steroids, unsaturated fats, carotenoids, nutrients, and biometals (Muszyńska et al., 2018). Metabolites from mushrooms have cell reinforcement, anticancer, and mitigating properties. These metabolites help decrease inflammation. Chronic inflammation in the body can lead to various neurogenerative, metabolic and autoimmune diseases. The anti-inflammatory effects of mushrooms are linked to their amino acid contents, which are well known to influence prostaglandin metabolism. Oyster mushrooms have amino acids like leucine, isoleucine, phenylanine and tyrosine, which have anti-inflammatory properties. Reishi and oyster mushrooms have been found to inhibit chronic inflammation, which contributes to other problems like diabetes, depression, Alzheimer's disease and other more serious problems. PUFAs present in mushrooms are the precursor molecules of eicosanoids, which act as signaling molecules that help in the proper regulation of cellular processes and immune responses. Eicosanoids help balance the inflammatory and anti-inflammatory responses of the immune system. Indole and terpene compounds present in mushrooms also have an anti-inflammatory role.

Anti-diabetic properties

Diabetes is a major problem in the modern world. It also alters the metabolism of carbohydrates, lipids, and fats in the body. Various *in vivo* and *in vitro* data revealed that the polysaccharide content of mushrooms displays anti-hyperglycemic effects due to their fibrous and non-fibrous bioactive compounds (Bello et al., 2017). They inhibit glucose absorption efficacy, enhance pancreatic beta-cell mass and increase insulin signaling pathways. These are low-glycemic-index and low-glycemic-load foods that can be easily consumed by diabetic patients (Nayak et al., 2021). Dietary supplementation of mushrooms can reduce the plasma glucose level due to the bioactivity of compounds like agmatine, sphingosine, pyridoxine, linolenic acid, oligosaccharides and arginine.

Anti-allergy properties

Allergies are an increasing problem worldwide. A chemically bioactive compound called inotodiol is a lanostanetriterpenoid present in mushrooms that has the activity to suppress mast cell function, which helps in decreasing severe symptoms like anaphylaxis in any allergy.

Neuroprotective properties

Mushrooms show different pharmacological exercises in anticipation of dementia in conditions such as Parkinson's and Alzheimer's disease. Mushroom consumption also helps to relieve mild symptoms of depression and anxiety. A neurological injury may occur due to an injury or wound in the cerebrum or spinal cord. Concentrates of mushrooms help speed recuperation from these sorts of wounds in the brain.

Conclusion

In conclusion, mushrooms are a valuable food source with exceptional nutritional and pharmacological properties. They are rich in essential nutrients and bioactive compounds that have been studied for their potential to prevent and treat various degenerative and metabolic diseases. Mushrooms exhibit anticancer, antioxidant, antibacterial, anti-inflammatory, anti-diabetic, anti-allergy, and neuroprotective properties. Incorporating mushrooms into a balanced diet can contribute to overall well-being and improved health outcomes.

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Unlocking the potential: integrating mushroom cultivation into farming systems for promoting sustainable agriculture and livelihood enhancement

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Abstract

The growing of mushrooms is increasingly being recognized as a sustainable agricultural technique that possesses considerable potential for enhancing rural people's standard of living. The production of mushrooms as part of agricultural systems offers a comprehensive approach that maximizes the use of available resources and encourages the practice of sustainable agriculture. This academic essay presents a thorough analysis of the financial, environmental, and social advantages that may be gained from incorporating mushroom production into existing agricultural practices. The article emphasizes major results and gives advice for successful implementation, drawing upon pertinent research as its source material.

Keywords: Mushrooms, Livelihood, Value addition, Farming system, Income generation.

Introduction

Cultivation of mushrooms, agricultural methods, sustainability, improving livelihoods, and agriculture are some of the keywords in this article. Agriculture that is conducted in a sustainable manner is absolutely necessary in order to guarantee food safety and enhance living conditions. Due to the nutritional value, therapeutic capabilities, and potential income-generating potential of mushrooms, mushroom gardening has emerged as a viable agricultural venture in recent years. An all-encompassing strategy that maximizes resource use and encourages sustainable farming practices is offered by the growing of mushrooms as a part of integrated agricultural systems. This article intends to provide farmers, academics, and policymakers with important insights by reviewing and analyzing the benefits and obstacles connected with incorporating mushroom production into farming systems.

Economic benefits of mushroom cultivation in farming systems

The cultivation of mushrooms offers numerous financial advantages to farming systems. There are significant financial advantages to be gained by incorporating mushroom production into existing agricultural systems. Alam et al. (2009) demonstrated that the integration of mushroom production with pond-based agricultural methods led to higher income and enhanced profitability. Ansari et al. (2014) brought attention to the economic potential of mushroom growing in the Eastern Himalayan area. They emphasized the significance that mushroom agriculture plays in the creation of revenue and the diversification of livelihoods. According to this research, the production of mushrooms not only helps diversify sources of revenue but also increases profitability and adds to the general viability of farms. The growing of mushrooms as part of agricultural systems offers a number of potential financial benefits, including higher income, greater profitability, and overall increased sustainability. Drawing on the findings of research that are pertinent to the topic at hand, this section discusses the financial benefits that come with integrated mushroom growing.

Increased capacity to generate income

The potential for enhanced income production is one of the primary economic benefits that may be realized by incorporating mushroom cultivation into existing farming systems. The research conducted on pond-based farming systems by Alam et al. (2009) places substantial emphasis on the large revenue that may be realized via the integration of mushroom production. Farmers have the potential to generate additional income from the sale of mushrooms and goods derived from mushrooms if they make the most of the resources and space at their disposal. The research carried out by Ansari et al. (2014) sheds light on the economic possibilities of growing mushrooms, particularly in the Eastern Himalayan area.

Multiple streams of revenue diversification

The production of mushrooms as an addition to already established agricultural practices offers a chance to diversify sources of revenue. Farmers who use traditional agricultural techniques sometimes rely on a restricted number of plant or animal species, which leaves them susceptible to the vicissitudes of the market and the hazards of the climate. Farmers have the ability to lessen their reliance on a particular agricultural commodity and diversify their sources of revenue by cultivating mushrooms. Not only does this diversity help to improve economic stability, but it also acts as a buffer against the unpredictability of the market.

Utilization of resources that are being underutilized

Integrated mushroom growing gives farmers the opportunity to make productive use of resources that would otherwise be wasted, such as crop leftovers, agricultural waste, and by-products of other manufacturing processes. The production of mushrooms may make use of a variety of organic substrates, including straw, sawdust, and agricultural leftovers, all of which would otherwise be thrown away. Farmers are able to gain cash from materials that were previously thought to be garbage thanks to a process that involves transforming these resources into lucrative mushroom biomass. This strategy helps to optimize resource utilization, which in turn leads to an improvement in profitability.

Opportunities for value addition and exploration of markets

The nutritional benefits, one-of-a-kind tastes, and therapeutic capabilities of mushrooms have contributed to their rise in popularity. The manufacture of mushroom-based goods such as dried mushrooms, mushroom powder, extracts, and pickled mushrooms presents chances for value addition that may be realized via the practice of integrated mushroom agriculture (Nayak et al., 2021). These value-added goods offer greater potential for profit for farmers as a consequence of their improved market worth, which allows them to command premium pricing. In addition, there is an ever-increasing demand for organic and environmentally responsible food items, which creates ideal market conditions for mushrooms that are grown using integrated farming techniques.

Creation of employment opportunities

The integrated farming of mushrooms has the potential to create economic possibilities, particularly in more remote locations. The cultivation, harvesting, processing, and selling of mushrooms are all operations that involve a significant amount of work. Farmers have the ability to provide extra job opportunities for themselves, their families, and society at large by incorporating mushroom production into their existing farming operations. The strengthening of rural livelihoods, the reduction of unemployment, and the improvement of socioeconomic circumstances are all contributed to by this.

Reduced costs associated with production

The growing of mushrooms as part of farming systems can help bring down the overall cost of production. Because it does not require a large amount of land or costly supplies, mushroom farming is an agricultural operation that is very cost-effective. In addition, the use of agricultural waste as a substrate helps to minimize the requirement for external inputs, which in turn helps to bring down production costs. Farmers may increase their profit margins and attain economic sustainability if they reduce their input costs as much as possible and make the most efficient use of their resources.

Market resilience

It is possible for farmers to increase their market resilience by diversifying their agricultural produce through integrated mushroom growing. Since the production cycle for mushrooms is very brief, growers are able to harvest many crops at different times throughout the year. This creates a more continuous income stream and lessens the dependency on products that are grown during certain seasons. In addition, the demand for mushrooms is quite consistent, and they are able to weather swings in the market better than other conventional agricultural commodities. As a consequence of this, integrated mushroom growing helps to contribute to increased market resilience for farmers, which in turn guarantees a more stable source of income.

The environmental benefits associated with the cultivation of mushrooms in agricultural systems

The growing of mushrooms as part of agricultural systems provides a number of benefits to the environment. Both Behera et al. (2004) and Gangwar et al. (2013) provided evidence that mushroom production is environmentally sustainable when it is integrated into farming systems. The creation of mushroom substrates by the recycling of agricultural waste, such as crop residues and organic matter, results in less waste being generated overall and encourages more effective exploitation of available resources. This strategy is consistent with the principles of sustainable agriculture, and it helps maintain healthy soil while reducing the amount of damage caused to the environment. These studies highlight the favourable influence that mushroom growing has on the cycle of nutrients in the soil and the fertility of the soil. The incorporation of mushroom production into agricultural systems not only results in economic gains, but it also makes substantial contributions to the protection of the environment. This section examines the environmental benefits of integrated mushroom growing, with a particular emphasis on increased resource efficiency, reduced waste production, and enhanced soil health.

Utilization of waste and decrease in waste

The utilization of waste and by-products from agricultural production is one of the most significant environmental benefits that come from mushroom farming. A wide variety of organic substrates, including crop leftovers, sawdust, wood chips, and straw, are suitable for the cultivation of mushrooms. Farmers are able to successfully recycle these agricultural wastes and transform them into useful mushroom biomass if they use them as substrates. This strategy lessens the load placed on the environment and fosters more environmentally responsible methods of waste management by cutting down on the quantity of agricultural waste that is accumulated.

The circulation of nutrients and the fertility of soils

The growing of mushrooms is an important component in both the cycling of nutrients and the increase of soil fertility. During the course of cultivation, mushrooms break down complicated organic molecules, which results in the release of vital nutrients into the substrate. As a consequence of this, the wasted mushroom substrate, also known as SMS, transforms into a substance that is abundant in nutrients and may be utilized either as an organic fertilizer or as a soil supplement. Farmers are able to improve soil fertility, encourage the cycling of nutrients, and lessen their need for artificial fertilizers if they incorporate SMS into their farming operations. According to the findings of research conducted by Behera et al. (2004), growing mushrooms can have a beneficial effect on the fertility of the soil on small and marginal farms.

Carbon Sequestration

The cultivation of mushrooms has been shown to help with carbon sequestration, which is an important factor in the fight against climate change. Mycelium, the component of the fungus that is responsible for vegetative growth, has the capacity to absorb and store carbon in mushrooms. By including mushroom production as part of farming systems, carbon may be stored in the biomass and organic matter, thereby lowering the agricultural sector's overall carbon footprint. This carbon sequestration capability can contribute to mitigating the effects of climate change by reducing greenhouse gas emissions and improving the overall sustainability of farming systems.

Protection of water resources

When compared to other forms of agriculture, the growing of mushrooms is one of the more water-efficient practices.

The cultivation process calls for moderate amounts of moisture, and while mushrooms may be produced using recycled water or even rainwater, the process itself requires moderate levels of moisture. This results in a lower need for water to be used for irrigation, which helps conserve valuable freshwater resources. Additionally, mushroom cultivation results in a negligible amount of water runoff, which eliminates the possibility of soil erosion and reduces the potential for water pollution. The growing of mushrooms helps to conserve water, which is consistent with environmentally responsible water management techniques.

Conservation of both biological diversity and ecosystems

The growing of mushrooms as part of agricultural practices has the potential to make a contribution to the protection of ecosystems and the preservation of biodiversity. Farmers can reduce the requirement for expanding their land holdings and altering natural habitats by using trash from agricultural production as a substrate in their operations. This contributes to the preservation of biodiversity hotspots as well as ecological equilibrium. In addition, mushrooms help maintain the general health of forest ecosystems by contributing to the breakdown of organic matter in forests and the process of nutrient cycling. This helps mushrooms play a part in forest decomposition.

Reduced amounts of chemical contributions

In most cases, the production of mushrooms calls for very little to no use of chemical inputs like pesticides and herbicides. Because of this, the level of environmental damage caused by traditional farming operations has decreased. Because they do not contain any chemical residues, mushrooms are considered a safe food product that is also kind to the environment. Farmers may lessen their dependency on synthetic pesticides and contribute to the preservation of soil and water quality by incorporating mushroom growing into their farming operations.

The preservation of available energy sources

The production of mushrooms is an example of an agricultural method that uses very little energy. When compared to the production of other types of crops, mushroom farming requires a considerably smaller amount of energy input. Utilizing technologies that are efficient in terms of energy consumption allows for the growing of mushrooms in a regulated environment, which includes the management of temperature and humidity. This helps to conserve energy resources and lowers the carbon footprint that is linked with the activities related with agriculture.

Implications for society as well as improvements in living conditions

The production of mushrooms as part of agricultural systems has enormous ramifications for society, notably in terms of the improvement it may bring to the standard of living of smaller-scale farmers. In their study, Swarnam et al. (2014) highlighted the significance of mushroom growing as a means of subsistence in tribal communities, highlighting its role in fostering self-sufficiency and enhancing food safety. Singh et al. (2019) illustrated the beneficial socio-economic effect that may be achieved in the mid-hills of Uttarakhand by combining mushroom production with fish-poultry-vegetable agricultural systems. The cultivation of mushrooms offers chances for production throughout the whole year, the creation of job opportunities, and the diversification of revenue streams, boosting the overall socioeconomic well-being of rural communities. The production of mushrooms as part of farming systems has significant repercussions for society as a whole, particularly for farmers working on a smaller scale. This section examines the social advantages and upgrades to livelihoods that are linked with integrated mushroom agriculture, with a particular emphasis on production throughout the entire year, employment generation, income diversification, and food security.

Production throughout the entire year

The capacity to maintain output throughout the year is one of the most significant societal benefits that accrue from incorporating mushroom gardening into existing agricultural practices. Mushrooms are one of the few crops that may be grown at any time of the year, despite the changing seasons, in contrast to other types of crops, which have defined growth seasons. Because of this ongoing production, farmers are able to maintain a constant supply of mushrooms, which not only offers them a consistent source of revenue but also increases the amount of food that is available for both commercial and subsistence consumption.

Creation of employment opportunities

Integrated mushroom production creates employment possibilities, which is especially beneficial in rural regions where there may be a scarcity of other work options. The cultivation, harvesting, processing, packing, and selling of mushrooms are all processes that involve a significant amount of work. Farmers have the ability to provide extra job opportunities for themselves, their families, and society at large by incorporating mushroom production into their existing farming operations. This helps to improve the socioeconomic conditions of farming communities, which in turn leads to the strengthening of rural livelihoods and a reduction in unemployment.

Income diversification

Farmers are able to reduce their reliance on a single agricultural commodity by cultivating many types of mushrooms at once through the practice of integrated mushroom agriculture. Many conventional farming methods concentrate on only a few species of plants or animals, leaving farmers exposed to the vicissitudes of the market as well as the effects of adverse weather. Farmers have the opportunity to increase their product variety and diversify their income sources when they begin cultivating mushrooms. This diversity of income ensures financial security, lowers the risks that are connected with crop failures, and improves overall livelihood resilience. Safety of Food and Adequate Nutrition Mushrooms have a high nutritional value and are rich in a variety of nutrients, including proteins, vitamins, minerals, and fibres that are essential to a healthy diet. The growing of mushrooms as part of farming systems increases food security by broadening the dietary options available and enhancing the amount of nutrients consumed. In addition, mushrooms may either be consumed fresh or processed into a variety of different food products, making them a source of food that is rich in nutrients throughout the year. Therefore, the incorporation of mushroom farming leads to increased food security and nutrition, particularly in regions where access to a variety of foods that are high in nutrition is limited.

Empowerment on a socioeconomic scale

Farmers gain agency because integrated mushroom production gives them access to a financially rewarding and environmentally responsible agricultural venture. Farmers enjoy better control over their financial resources and the ability to invest in education, healthcare, and other important requirements when they generate additional money. This gives farmers a competitive advantage. Agricultural households see an improvement in their quality of life and general well-being as a result of this socioeconomic empowerment. Farmers will have a greater sense of pride and ownership of their land as it helps them become less reliant on other sources of support and more capable of supporting themselves.

Knowledge and skill development

Farmers will need to learn new information and skills in order to successfully cultivate mushrooms and integrate them into their farming operations. The implementation of growing techniques for mushrooms raises the level of farmers' technical ability, which in turn encourages ongoing education and the expansion of their capabilities. Farmers develop competence in many facets of mushroom production, including the preparation of substrates, the creation of spawn, culture techniques, the management of pests, and the development of marketing strategies. This knowledge and skill development contribute to the improvement of agricultural practices and empower farmers to seek new opportunities within the agricultural industry.

Integration of society and progress of the community

The production of integrated mushrooms has the potential to promote social bonding as well as community development. Farmers that cultivate mushrooms frequently organize cooperatives or other types of self-help organizations in order to sell their goods collectively, have access to resources, and share their expertise and experiences with one another. These coordinated efforts establish social bonds, encourage the flow of knowledge, and make collaborative decision-making procedures easier to accomplish. Farmers can handle shared difficulties, negotiate better pricing, and advocate for their collective interests if they work together, leading to broader community growth as a result of their efforts. Obstacles to Overcome and Suggestions for Improvement In spite of the many advantages, there are a few obstacles to overcome when attempting to incorporate mushroom production into existing farming systems. Common obstacles include a lack of proper market linkages, restricted access to high-quality spawn, and insufficient levels of technical knowledge. According to Franzel et al. (2019), farmer-to-farmer extension programmes and capacity-building activities are very necessary in order to address these issues. Increasing the amount of effort put into research and development, fostering the sharing of knowledge, and setting up market networks are all things that can help the effective implementation of integrated mushroom farming systems.

Challenges facing integrated mushroom cultivation in farming systems and recommendations for moving forward

Integrated mushroom growing in farming systems offers a multitude of benefits, yet farmers may face a number of problems when attempting to implement this practice. It is absolutely necessary for a successful implementation to first comprehend and then handle these problems. The following are some examples of common difficulties:

1. **Inadequate knowledge of mushroom growing techniques:** The growing of mushrooms calls for particular knowledge and abilities. There is a good chance that many farmers do not have the required level of technical skills to begin and successfully maintain mushroom production. This might lead to issues in the right preparation of the substrate, the generation of spawn, the control of diseases, and the procedures for harvesting.

2. **Lack of access to high-quality spawn:** Successful mushroom production requires the use of spawn of the highest possible quality. However, there may be difficulties for small-scale farmers in gaining access to dependable and high-quality spawn sources. In some areas, the supply of spawn, particularly of types of mushrooms that are highly sought-after, may be limited.

3. **Infrastructure and investment:** Establishing the right infrastructure for mushroom growing, such as mushroom houses or controlled settings, may be a substantial problem for small-scale farmers. Examples of such infrastructure include controlled environments and mushroom houses. The investment that is essential for establishing infrastructure and procuring the appropriate equipment may be hampered if there are insufficient financial resources and restricted access to credit.

4. **Management of pests and diseases:** The production of mushrooms is prone to the attack of several pests and diseases, each of which can have a substantial negative effect on yield or quality. Mites, nematodes, and fungal infections are only some of the diseases and pests that may be managed effectively via the use of proactive management techniques and the understanding of proper control procedures.

5. **Access to markets and marketing strategies:** It is possible that farmers will experience difficulties gaining access to markets and developing marketing strategies that are effective for marketing their mushroom output. The sale and distribution of mushrooms can be hampered by limited market connections, a lack of market intelligence, and inappropriate marketing techniques, which in turn can have an adverse effect on profitability.

Recommendations

The following advice, which should be taken into consideration, can be helpful in overcoming these problems and maximizing the potential of integrated mushroom cultivation:

1. **Training and extension services:** It is vital to develop the farmers' technical knowledge and abilities in mushroom farming by providing them with training and extension services. Training programmes and seminars can be organized to communicate best practices, techniques for producing spawn, disease management tactics, and post-

harvest handling procedures by governmental agencies, agricultural institutions, and non-governmental organizations (NGOs).

2. **Increasing the capacity of supply chains:** It is essential to create supply chains that are dependable and easily available in order to obtain quality spawn. The creation of spawn production units can be supported by governments and other institutions, and these organizations can also instruct farmers on how to produce spawn. This will assure a regular supply of spawn of high quality while simultaneously minimizing reliance on other sources. Financial assistance and incentives: In order to assist farmers in the process of constructing mushroom farming infrastructure, governments and other financial institutions may provide the necessary financial assistance and incentives. This may take the form of subsidized loans, grants, or subsidies and may be used for the construction of mushroom houses, the purchase of equipment, or the implementation of controlled environment systems.

3. **Management of integrated pests and diseases:** It is very necessary to advocate for integrated pest and disease management methods if one wants to reduce the amount of damage caused by pests and diseases. Farmers may get education on how to properly identify pests, as well as cultural techniques, biological management strategies, and the appropriate application of pesticides. It is possible to lessen the severity of the damage caused by illnesses and pests through consistent monitoring and prompt response.

4. **Market development and links:** Efforts should be made to build strong market links for mushroom growers. Creating farmer-producer organizations or cooperatives, developing direct marketing networks, and linking farmers with wholesale customers, merchants, and food processing businesses are some examples of what this entails. Farmers may be able to get higher prices for their goods if they have access to more markets and are provided with information about those markets.

5. **Research and development**: Efforts that are continually made in the areas of research and development are of the utmost importance in order to solve specific issues and enhance mushroom cultivation procedures. Institutions dedicated to research ought to focus their efforts on the development of region-specific technologies, disease-resistant strains, and new production practices. In addition, research can be carried out in order to investigate value-added goods and marketing techniques with the purpose of optimizing profits.

Conclusion

A comprehensive and environmentally responsible approach to farming may be achieved through the production of mushrooms as part of agricultural systems. Several studies point to the economic, environmental, and social benefits that might result from the integration of these systems. Mushroom production contributes to sustainable agriculture and rural development in a number of ways, including the diversification of revenue sources, promotion of resource efficiency, and improvement of livelihoods. To be effective in integrating mushroom production into existing agricultural systems, however, it is essential to address the problems through the utilization of suitable support mechanisms. Conclusion: The development of mushrooms as part of agricultural systems has tremendous promise for the improvement of both environmentally friendly agriculture and people's standard of living. This in-depth analysis has brought to light the economic, environmental, and social benefits connected with the incorporation of mushroom production into farming systems, as well as the problems that need to be addressed for the effective implementation of this strategy. Integrating mushroom farming into an existing operation result in a greater diversity of income streams, an increase in profitability, and an improvement in the farm's overall viability. It presents prospects for enhanced revenue production, diversification of income streams, and the creation of job opportunities. Farmers may improve their economic sustainability and resistance to market volatility by making use of resources that are not being exploited to their full potential and adding value to their crops via the development of mushroom-based goods. In terms of the environment, integrating mushroom farming adds to the efficiency of resource use, the reduction of waste, the improvement of soil health, and the conservation of energy resources. It makes the use of agricultural waste possible and encourages the practice of environmentally responsible waste management. The growing of mushrooms improves nutrient cycling, soil fertility, and carbon sequestration. As a result, this activity contributes to the mitigation of climate change and supports the principles of sustainable agriculture. Water conservation, the preservation of biological variety, and the reduction of the use of chemical inputs are all additional factors that contribute to environmental sustainability. Integrating mushroom growing into agricultural practices can improve people's livelihoods, lead to greater food security, and give farming communities more agency. It allows for output throughout the whole year, as well as job options and diversified revenue streams. Mushroom production contributes to societal well-being and economic independence since it increases the availability of food, the amount of nutrients consumed, and the socioeconomic circumstances. Additional social advantages linked with integrated mushroom growing include the growth of knowledge and skills, the maintenance of social solidarity, and the improvement of community development. However, there are obstacles that need to be overcome in order to successfully incorporate mushroom production into existing farming systems. These constraints include inadequate technical expertise, the availability of quality spawn, requirements for infrastructure and investment, the management of pests and diseases, market access and marketing strategies, and so forth. Implementing recommendations such as farmer training and extension services, building supply chains for spawn, giving financial assistance and incentives, and enhancing market connections are some of the things that may be done to solve the difficulties that have been outlined. In conclusion, the production of mushrooms may be integrated into agricultural systems, which unlocks the potential for sustainable agriculture and increases the quality of life for people. It provides a comprehensive strategy that makes the most efficient use of available resources, emphasizes the importance of sustainability, and makes a positive contribution to the well-being of the economy, the environment, and society. Farmers, researchers, and policymakers may leverage the benefits of integrated mushroom growing by addressing the problems and following the proposed techniques. This will pave the way for a more sustainable and successful agricultural future.

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5.3 The RESULTS AND DISCUSSION should preferably be combined to avoid repetition. Results should be presented in the tabular form and graphs when feasible but not both. The colour figures and plates, are printed in case only, when information would be lost if reproduced in black and white. Mean result with the relevant standard errors should be presented rather than detailed data. The data should be so arranged that the tables would fit in the normal layout of the page setup. Self- explanatory tables should be typed on separate sheets bearing appropriate titles. The tabular content should not exceed 20% of the total text. Any abbreviation used in a table must be defined in that table preferably as the footnote. Paginate the tables in respective series with the text. All tables should be cited in the text of the article. If an explanation is needed, use an abbreviation in the body of the table (e.g., DM) and explain clearly in footnotes what the abbreviation means. References to footnotes in a table are specified by superscript numbers, separately for each table. Superscript alphabets are used to designate statistical significance. Use a lower-case p to indicate probability values (i.e., p<0.05). In general, use numerals. When two numbers appear adjacent to each other, spell out the first (i.e., eight 1-day old chicks rather than 8 1-d old chicks). In a series using some numbers less than 10 and some more than 10 use numerals for all (i.e. 2 villages, 6 communities and 15 schools). Do not initiate a sentence with a numeral, it is better to spell it out or rearrange the sentence. Abbreviate the terms month (m), week (w), hour (h), minute (min) and second (sec) when used with a number in the text but spell them out when they are used alone. Do not use a hyphen to indicate inclusiveness (e.g., use 10 to 15 mg or wk 1 and 5 not 10-15 mg or wk 1-5). Use Arabic numerals with abbreviated units of measure: 12 g, 7 d, $10.00, 5% and numerical designations in the text: exp 2, group 4, etc. The images should be avoided if possible. The printing of figures needs additional payment of APC. If necessary, the author is required to submit high-resolution images, preferably with the initial submission but no later than revision stage. Electronic images (figures and schemes) must have a minimum resolution of 600 dpi for line drawings (black and white) and 300 dpi for colour or greyscale. Colour figures must be supplied in CMYK not RGB colours. Be ensured that the prepared electronic image files print at a legible size (with lettering of at least 2 mm). do not save the images as Portable Document Format (PDF). Please ensure that the figure is clearly labelled with its figure number. Original artwork: If you are unable to submit electronic artwork, please provide two sets of all figures as high-quality glossy prints at the size that they are to appear in print. One set should be unlabeled. The text content should elaborate on the tabular data, but not be repeated extensively within the text. Sufficient data, all with the index of variation attached, should be presented to allow the reader to interpret the results of the experiment. The discussion should interpret the results clearly and concisely in terms of proper mechanisms and should integrate literature results with the research findings to provide the reader with a wide base on which to accept or reject the hypotheses tested. Results and references to tables and figures already described in the RESULTS section therefore they should not be repeated in the DISCUSSION section.

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For whole books Author(s), year. Title. (Ed.). Edition if any, Number of pages. Publisher, address.

Snedecor G W and Cochran W G. 1994. Statistical Methods, 6th edn, 491p. Iowa State University Press, Ames.

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Clark J A and McArthur A J. 1994. Thermal Exchanges. Livestock Housing.1edn, pp. 97-122. (Eds) Wathes C M and Charles D R. CAB INTERNATIONAL, Wallingford, UK. For Symposium Devegowda G, Raju M V L N, Afzali N and Swamy H V L N. 1998. Mycotoxin picture world-wide: Novel solutions for their counteraction. Proceedings of 14th Alltech's Annual Symposium on Biotechnology in the Feed Industry. pp. 241-55. 5 May 1997. Bangalore.

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