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AZOLLA PINNATA SUPPLEMENTATION EFFECTS IN POST-WEANED GOAT KIDS

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Abstract

Background: *Goats need good nutrition for healthy growth.* Azolla pinnata, *a water fern, is rich in protein and nutrients. Feeding it to young goat kids may improve their growth and blood health.*

Aims: *To evaluate the effects of different levels of* Azolla pinnata *supplementation on the growth performance and blood parameters of post-weaned goat kids under intensive management.*

Methodology: *Twelve male goat kids (n=12), aged 5 to 6 months were purchased from a local market and were assigned randomly to three (3) groups of 4 each. Group A was the control group receiving only a basal diet while Group B received a basal diet + 100 g of concentrate mixed with 150 g of Azolla pinnata; whereas Group C received a basal diet + 150 g of concentrate mixed with 250 g of Azolla pinnata.*

Results: *The initial weight of goats in their respective groups was: 8.5 kg (A), 8.2 kg (B), and 9.0 kg (C) and the final weights were: 12.25 kg (A), 15.5 kg (B), and 17.5 kg (C). A significant difference ($P < 0.05$) in body weight was observed on Day 45 in all groups and this trend continued throughout the duration of the experiment. The initial lengths of all three groups were: 43.18 cm (A), 45.72 cm (B), and 48.26 cm (C); while their final lengths were: 46.99 cm (A), 50.8 cm (B), and 55.88 cm (C). From Day 45 onwards, groups showed significantly different body lengths ($P < 0.05$) and body height measures with Group C consistently having the highest values throughout the study period. After the 45th day, heart girth also exhibited significant differences ($P < 0.05$) among the groups - from Day 90, Group C's heart girth was significantly greater than those of Groups A and B ($P < 0.05$). All hematological parameters measured were significantly different ($P < 0.05$) between groups, specifically compared to groups A, B and C, regarding erythrocyte count (A = $0.190\times10^6/\mu L$; B = $0.320\times10^6/\mu L$; C = $0.435\times10^6/\mu L$) and MCV (A = 56 fL; B = 62 fL; C*

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= 63 fL). There were no observed differences (P > 0.05) for all other hematological parameters analyzed (hemoglobin (Hb), mean corpuscular hemoglobin concentration (MCHC), hematocrit (HCT), total leukocyte count (WBC), neutrophils, lymphocytes, monocytes, platelet count (MPV), and total serum protein (TSP).

Conclusion: *Overall, it was concluded that Azolla pinnata supplementation significantly improves the growth performance of goat kids when compared to the control and certain hematological parameters as compared to control group.*

INTRODUCTION

Livestock is the main driver of the economy in Pakistan's rural areas, where an estimated 8 million livestock farms now operate, making livestock a lucrative economic option for rural families. Livestock has been a vital mainstay for those rural families that rely on livestock as a source of income, with some estimating that it contributes approximately 35% to 40% of their total income. The livestock economy nationally is also a key contributor to the growth of Pakistan's agriculture sector, with total agricultural value added equaling about 60.84% of Pakistan's total agricultural economic value and 14.63% of the total GDP of Pakistan for the fiscal year ending June 30, 2024. The 2024 Economic Survey of Pakistan estimates that the goat population has a total of around 87 million goats, which is around 37% of the total number of ruminants in Pakistan. The survey also states that the goat meat and milk production for 2023-24 is estimated at approximately 1,074 thousand tons. Of the 34 different goats raised in Pakistan, Teddi, Beetal, and Kamori have the most numbers of animals in each breed. The average body weights of the adult goats typically run from 20 to 70 kg at maturity. Goats are important food animals along with providing an excellent source of food high in biological value; therefore, goats play a major role in providing or fulfilling the increasing need for more animal protein to meet the demands of the growing population. One way to help aid in the development of goat breeding for improved productive and reproductive performance is by understanding the production potentials of goats in different environmental conditions, which are locations that have different climatic conditions, through genetic selection and the implementation of proper management practices using modern scientific methodologies. Therefore, although the need for increased meat supply spaces has increased globally, there is very little academic attention given to the productive and reproductive performance of goat populations in Pakistan (Moaeen-ud-Din, 2020).

Of the regions producing goat breeds within the country of Pakistan, the Province of Sindh is a significantly prosperous area. It has ten differently recognised goat breeds including Kamori, Tapri, Bugi-Tori, Pateri, Kachan, Jattan, Lohri, Chappar, Barri, Thari. All these goat breeds possess characteristics that fit well with the local climatic and environmental conditions of the practicing location (Moaeen-ud-Din et al. 2006). Goats are fast-growing animals that possess a typically high rate of reproduction; many goats are thought to be among the most fertile livestock species within domesticated species, and their rate of conception can be as high as 90% (Ince 2010). The fact that goats are recognized as being among the fastest growing farm animals can be attributed in large part to their high level of reproductive efficiency. Goats have exhibited high levels of fertilization (in a large percentage of cases) when raised under good management practices (Agossou & Koluman 2018). The farming of goats for religious purposes such as the sacrifice of animals for Eid-ulAdha provides an important source of economic benefit to those who have established this business model within the more sustainable agricultural sector in Central and Southern Punjab. Intensive systems are often characterized by managing all aspects of the goat's diet through carefully controlled feed and systematic feeding management practices. Maximizing body condition is an important component of animal welfare and profit potential. A wide range of phenotypic and genotypic diversity exists in both intra-breed and inter-breed comparisons, which can be reflected through morphometric measures, growth rates,

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reproductive performance, and other physiological characteristics. Adult goat weights can vary from 20-70 kg but can be as much as four times that under optimal nutritional and genetic conditions (Muhammad et al., 2015). Because of their adaptation to many different agro-ecological settings and their natural browsing habits enabling them to efficiently utilize a broad range of shrubs, herbs, and trees, goats are highly versatile ruminants capable of being productive in both intensive and semi-intensive production systems based on their physiological ability to tolerate stress and convert feed to milk and meat efficiently. Goats have also been given the nickname "poor man's cow" because of their relatively small size, multifunctional support, and ability to thrive in limited-resource settings, thus playing a vital role in the livelihood of smallholder farmers (Khan & Ashfaq, 2018).

Among non-conventional feed sources, *Azolla pinnata*, an aquatic fern that grows on stagnant water bodies (e.g., watercourses, lakes, and artificial containers such as plastic tubs), is an uncommon example of a feed resource. The family Azollaceae includes *Azolla pinnata*, an aquatic fern that also exhibits rapid biomass accumulation and high levels of nutrient density relative to other feed sources. Azolla is primarily found growing on the surface of standing or slow-moving water bodies (e.g., watercourses, rice paddies, and lakes). It can also be grown in controlled settings such as cement-lined tanks or plastic-tubbed environments. Most of the protein in Azolla comes from its mutualism with the nitrogen-fixing cyanobacterial species, Anabaena azollae (Sharma 2021).

In recent years, rising interest has been paid to *Azolla pinnata*, commonly known as either the Water Fern or Duckweed Fern. It is a type of free-floating aquatic plant (aquatic pteridophytes) that may potentially serve as a sustainable and nutritionally complete nonconventional feed source for livestock animals. Its high levels of protein, coupled with the fact that it grows rapidly, is easy to grow in many different types of aquatic conditions, and grows in partnership with nitrogen-fixing cyanobacteria (*Anabaena azollae*) are just a few of the traits that give *Azolla pinnata* its high crude protein content, essential amino acid and mineral content and bioactive properties that make it a valuable addition to ruminant and monogastric animal diets. Additionally, *Azolla pinnata* requires constant access to water and can flourish under full sunlight or partial shade from trees. This plant also is one of the highest sources of protein available for livestock, with a protein content of typically between 20-30% (Kumari et al., 2021), and is also rich in vitamins such as vitamin A and Vitamin

B12, which are very important to the overall health of livestock (Mathur et al., 2013). Essential mineral sources from plants include calcium, potassium, magnesium, and iron in large amounts. The advantages of this crop include its ease of cultivation, low water requirements, high level of productivity, and very high nutritional value (Prabina & Kumar, 2010).

Because of its characteristics, *Azolla pinnata* may prove to be a potential sustainable feed supplement for livestock. The nutrients contained in *Azolla pinnata* will add value as a feed ingredient. Lysine, methionine, and tryptophan (essential amino acids) are nutrients that are generally not abundant and therefore limited in conventional feed sources (Kumar et al, 2018). Additionally, Azolla is a source of several important vitamins, minerals, and bioactive compounds (such as phenolic and flavonoid compounds), which contribute to the health of livestock and their productivity (Rashad, 2021). There is evidence that Azolla is a rich source of nutrients including protein, lipids, minerals and vitamins (Alalade et al, 2007). Therefore, due to its bio-composition, Azolla could potentially provide economic, efficient and sustainable alternatives to traditional animal feed (Mahanthesh et al., 2018). This study will investigate the effects of dietary inclusion of *Azolla pinnata* at various levels on growth performance, blood parameters and the potential for improving the value of Azolla for livestock due to its high levels of protein, vitamins and minerals to support animal health and productivity.

MATERIAL AND METHOD

Experimental site

The trial was designed at Sindh Agricultural University in Tandojam, Pakistan from May

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15th to August 15th, 2025 with a duration of 90 days including the Adaptation Period.

Adaptation and management of goat kids

Twelve goat kids aged between five and six months, and weighing between 8 and 9 kg post-weaning, were included in this study. All the animals were tagged, dewormed and vaccinated before the start of the trial. Throughout the trial period, animals were maintained in an intensive management system, provided with a basal diet and unlimited access to clean drinking water.

Table 1: Detail of allotment of treatment in feeding trials

Groups	No. of Kids	Housing and feeding details
A (Control)	4	Intensive feeding with basal diet
B (Treatment)	4	Intensive feeding with basal diet, 100 g concentrate + 150 g *Azolla pinnata*
C (Treatment)	4	Intensive feeding with basal diet, 150 g concentrate + 250 g *Azolla pinnata*

Note: Concentrate was provided based on body weight as per thumb rule

Feeding Regimen

As indicated in the experiment's design, animals were supplied with green forage as well as concentrating rations in daily amounts. During the trial period, both Groups B and C received an added amount of *Azolla pinnata* at the specified supplementation levels. Feed intake was monitored continuously, while daily health management activities to assist with uniformity of feeding and the health of the animals were carried out.

Parameters of research

Growth performance of male goat kids

Weight was measured with help of automatic weighing balance machine (Yameto made in China), available at Livestock Experimental Station, Sindh Agriculture University Tandojam.

Initial body weight (kg)

Initial body weight of goat kids was measured with the help of weighing machine.

Fortnightly body weight (kg)

Weight gain was measured based on the increase in fortnightly body weight over the initial body weight.

Final body weight (kg)

At the end of the experimental trial, the total live weight was measured using an electrical weighing balance.

Body conformation (cm)

The linear body conformation (cm) was recorded at fortnightly intervals using a measuring tape, including body length (distance between the shoulder and pin bone), heart girth (circumference around the heart), and height at withers (perpendicular distance from the ground to the withers in a level standing position).

Blood parameters

At the end of the trial, blood was collected from the jugular vein of the experimental animals into vacutainers containing ethylene diamine tetraacetic acid (EDTA), polymer gel and powdered glass clot activator. The blood samples were then transported to the Central Veterinary Diagnostic and Research Laboratory (Tandojam) for analysis of complete blood count (CBC) and total serum protein (g/dl).

STATISTICAL DESIGN

The data was tabulated and statistically analyzed by using ANOVA and LSD tests through computerized statistical package i.e., student addition of Statistix (SXW), version 8.1 (Copy right 2005, Analytical software, U.S.A).

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RESULTS

Effect of different levels of *Azolla pinnata* supplementation on weight gain of post weaned goat kids under intensive management system

Data of Table 2 shows that across all treatment groups, a gradual and consistent increase in body weight gain was observed throughout the 90-day period. However, the final measurement at Day 90 confirmed the significant effect of *Azolla pinnata* supplementation, particularly at the 250 g level (Group C) achieved 17.5 kg, followed by group B at 15.5 kg and group A at 12.25 kg. Group C showed significantly higher ($P < 0.05$) body weight gain compared to both group B and A.

Table 2: Weight gain of post weaned goat kids under intensive management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
Initial	8.5^{c}	8.2^{b}	$9.0c^{a}$
15th Day	8.5^{c}	8.2^{b}	9.0^{a}
30th Day	9.0^{c}	9.0^{b}	9.5^{a}
45th Day	9.57^{c}	9.75^{b}	10.5^{a}
60th Day	10.12^{c}	11.12^{b}	11.5^{a}
75th Day	11.5^{c}	14^{b}	15.5^{a}
90th Day	12.25^{c}	15.5^{b}	17.5^{a}
LSD	0.2162		
SE±	0.1066		
P-value	0.0000		

Effect of different levels of *Azolla pinnata* supplementation on the body length of post weaned goat kids under intensive management system

Table 3 reveals that throughout the 90-day trial, all treatment groups showed a consistent and progressive increase in body length. However, the most notable and sustained growth was observed in group C with 55.88cm which received basal diet, 150 g concentrate mixed with 250 g *Azolla pinnata* daily. In comparison, group B measured 50.80 cm and group A 46.99 cm. Group C was significantly higher ($P < 0.05$) than in groups A and B.

Table 3: Body length of post weaned goat kids under intensive management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
Initial	43.18^{c}	45.72^{b}	48.26^{a}
15th Day	43.18^{c}	45.72^{b}	48.26^{a}

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30th Day	43.18[c]	45.72[b]	48.26[a]
45th Day	44.45[c]	46.99[b]	49.53[a]
60th Day	45.72[c]	48.26[b]	53.34[a]
75th Day	45.72[c]	48.26[b]	54.61[a]
90th Day	46.99[c]	50.8[b]	55.88[a]
LSD (0.05)	0.4906		
SE±	0.2419		
P-value	0.0000		

Effect of different levels of *Azolla pinnata* supplementation on the body height of post weaned goat kids under intensive management system

Table 4 shows that across all treatment groups, a gradual and consistent increase in body height was observed throughout the 90-day period. However, the greatest height gains were consistently recorded in group C with 59.69 cm which received basal diet, 150 g concentrate mixed with 250 g Azolla pinnata daily, followed by group B at 54.61 cm, and group A at 50.80 cm. Although Group C consistently exhibited the highest height measurements across all time points were significantly higher ($P < 0.05$) than in groups A and B.

Table 4: Body height of post weaned goat kids under intensive management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
Initial	43.18[c]	45.72[a]	48.26[a]
15th Day	43.18[c]	45.72[a]	48.26[a]
30th Day	43.18[c]	45.72[b]	48.26[a]
45th Day	44.45[c]	46.99[b]	50.8[a]
60th Day	45.72[c]	48.26[b]	52.1[c]
75th Day	48.26[c]	53.34[b]	55.88[a]
90th Day	50.8[c]	54.61[b]	59.69[a]
LSD	0.4906		
SE±	0.2419		
P-value	0.0000		

Effect of different levels of *Azolla pinnata* supplementation on the heart girth of post weaned goat kids under intensive management system

Table 5 demonstrates that the body girth of goat kids reared under intensive management was influenced by varying levels of concentrating supplementation mix-up with *Azolla pinnata*, as observed over a 90-day period. However, the greatest height gains were consistently recorded in group C which received basal diet, 150 g concentrate mixed with 250 g *Azolla pinnata*

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daily, followed by group B at 54.61 cm, and group A at 50.80 cm. Although Group C consistently exhibited the highest height measurements across all time points were significantly higher ($P < 0.05$) than in groups A and B.

Table 5: Heart girth of post weaned goat kids under intensive management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
Initial	40.64^{c}	43.18^{b}	45.72^{a}
15th Day	40.64^{c}	43.18^{b}	45.72^{a}
30th Day	40.64^{c}	43.18^{b}	45.72^{a}
45th Day	43.18^{c}	45.72^{b}	49.53^{a}
60th Day	43.18^{c}	48.26^{b}	52.07^{a}
75th Day	44.45^{c}	49.53^{b}	54.61^{a}
90th Day	45.72^{c}	50.8^{b}	55.88^{a}
LSD	0.001774		
SE±	0.000874		
P-value	0.0000		

Effect of different levels of *Azolla pinnata* supplementation on hematocrit (%) of post weaned goat kids under intensive management system

Table 6 reals that the highest hematocrit value (1.3%) was recorded in group C which received basal diet, 150 g concentrate mixed with 250 g *Azolla pinnata* daily. A slightly lower hematocrit of (1.1%) was observed in the group B fed basal diet, 100 g concentrate mixed with 150 g of *Azolla pinnata*, while the control group A which received basal diet exhibited the lowest hematocrit level at (1.01%). Statistical analysis indicated no significant effect of treatment on hematocrit values ($P > 0.05$).

Table 6: Hematocrit (%) of post weaned goat kids under intensive management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
90th Day	1.01 g/dl^{c}	1.1 g/dl^{b}	1.3 g/dl^{a}
LSD	0.053		
SE±	0.0011		
P-value	0.13		

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Effect of different levels of *Azolla pinnata* supplementation on hemoglobin (g/dl) of post weaned goat kids under intensive management system

Data of the table 7 shows that the hemoglobin level (9.75 g/dl) was observed in group C which received basal diet, 150 g concentrate mixed with 250 g *Azolla pinnata* daily. Compared to group B (9.00 g/dl) while group A lowest hemoglobin concentration (8.70 g/dl) was observed. Statistical analysis indicated no significant differences (P > 0.05) among the treatment groups.

Table 7: Hemoglobin (g/dl) of post weaned goat kids under intensive management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
90th Day	8.7 g/dl[c]	9.0 g/dl[b]	9.75 g/dl[a]
LSD	0.923		
SE±	0.408		
P-value	0.14		

Effect of different levels of *Azolla pinnata* supplementation on erythrocytes (× 106/µL) of post weaned goat kids under intensive management system

Data of table 8 shows that the average erythrocyte count (0.435 × 10^6/µL) was observed in the treatment group C which received basal diet, 150 g concentrate mixed with 250 g *Azolla pinnata* daily. While average erythrocyte level (0.320 × 10^6/µL) was recorded in the group B received basal diet, 100 g concentrate mixed with 150 g of *Azolla pinnata*. Despite the lowest erythrocyte concentration (0.190×10^6/ µL) being found in the control group A, which did not receive *Azolla pinnata* supplementation. Statistical analysis indicated significant differences (P < 0.05) among the treatment groups.

Table 8: Erythrocytes (× 106/µL) of post weaned goat kids under intensive management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
90th Day	0.190×10^6/ µL [c]	0.320×10^6/ µL [b]	0.435×10^6/ µL [a]
LSD	0.043		
SE±	0.019		
P-value	0.0000		

Effect of different levels of *Azolla pinnata* supplementation on mean corpuscular volume (fl) of post weaned goat kids under intensive management system

Data of table 9 reveals that the average MCV value (63 fL) was recorded in the group C supplemented basal diet, 150 g concentrate mixed with g *Azolla pinnata* daily. Although slightly lower MCV (62 fL) was observed in group B supplemented with basal diet, 100 g concentrate mixed with 150 g *Azolla pinnata*, while the control group A, which received no *Azolla pinnata* exhibited the lowest MCV value (56 fL). Statistical analysis indicated significant differences (P < 0.05) among the treatment groups.

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Table 9: Mean corpuscular volume (fl) of post weaned goat kids under intensive management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
90th Day	56 fl[c]	62 fl[b]	63 fl[a]
LSD	1.16		
SE±	0.363		
P-value	0.01		

Effect of different levels of *Azolla pinnata* supplementation on mean corpuscular hemoglobin concentration (g/dl) of post weaned goat kids under intensive management system

Data of table 10 demonstrates that average MCHC value (32.71 g/dl) was observed in the group C receiving basal diet, 150 g concentrate mixed with 250 g of *Azolla pinnata* daily, followed by group B (32.44 g/dl), which received basal diet, 100 g concentrate mixed with 150 g *Azolla pinnata*. The control group A, which received just basal diet no *Azolla pinnata* exhibited the lowest MCHC (31.15 g/dl). Although a numerical increase in MCHC was observed with higher *Azolla pinnata* supplementation. These results suggest that *Azolla pinnata* had no statistically significant ($P > 0.05$) effect on red blood cell hemoglobin concentration.

Table 10: Mean corpuscular hemoglobin concentration (g/dl) of post weaned goat kids under intensive management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
90th Day	31.15 g/dl[c]	32.44 g/dl[b]	32.71 g/dl[a]
LSD	0.556		
SE±	0.246		
P-value	0.29		

Effect of different levels of *Azolla pinnata* supplementation on leukocytes (x10³/µL) of post weaned goat kids under intensive management system

Data of table 11 shows that average WBC count ($10.27 \times 10^3/\mu L$) was recorded in the group C received basal diet, 150 g concentrate mixed with g *Azolla pinnata* daily. A slightly lower count ($10.00 \times 10^3/\mu L$) was observed in group B supplemented with basal diet, 100 g concentrate mixed with 150 g of *Azolla pinnata*, while the control group A which received no *Azolla pinnata* exhibited the lowest WBC count ($9.22 \times 10^3/\mu L$). Statistical analysis revealed that the differences were not significant ($P > 0.05$).

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Table 11: Leukocytes (x10^3/µL) of post weaned goat kids under management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
90th Day	9.22 × 10^3/µL^c	10 × 10^3/µL^b	10.27 × 10^3/µL^a
LSD	1.572		
SE±	0.695		
P-value	0.27		

Effect of different levels of *Azolla pinnata* supplementation on neutrophils (%) of post weaned goat kids under intensive management system

Results of table 12 reveal that the average neutrophil level (23.35%) was recorded in group C supplemented with basal diet, 150 g concentrate mixed with 250 g *Azolla pinnata* daily, followed by the group B received basal diet,100 g concentrate mixed 150 g *Azolla pinnata*, which showed (22.60%). The control group A, which did not receive any *Azolla pinnata*, exhibited the lowest neutrophil percentage (22.30%). Statistical analysis revealed that the differences were not significant (P > 0.05).

Table 12: Neutrophils (%) of post weaned goat kids under intensive management System

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
90th Day	22.30%^{c}	22.60%^{b}	23.35%^{a}
LSD	0.477		
SE±	0.211		
P-value	0.45		

Effect of different levels of *Azolla pinnata* supplementation on lymphocytes (%) of post weaned goat kids under intensive management system

Results of table 13 show that the average lymphocyte calculated (64.90%) was recorded in the group C fed basal diet, 150 g concentrate mixed with 250 g *Azolla pinnata* daily. A slightly lower percentage (64.74%) was observed in the group B received basal diet, 100 g concentrate mixed with 150 g concentrate *Azolla pinnata*, while the control group A, which received no *Azolla pinnata*, showed the lowest lymphocyte level (63. 45%). These results suggest that *Azolla pinnata* supplementation had no significant (P>0.05) effect on lymphocyte count in goat kids.

Table 13: Lymphocytes (%) of post weaned goat kids under intensive management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
90th Day	63.45%^{c}	64.74%^{b}	64.90%^{a}
LSD	0.676		
SE±	0.299		
P-value	0.44		

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Effect of different levels of *Azolla pinnata* supplementation on monocytes (%) of post weaned goat kids under intensive management system

Results of table 14 describe that the average monocyte count (12.75%) was counted in the group C receiving basal diet, 150 g concentrate mixed with 250 g *Azolla pinnata* daily, followed by the group B receiving basal diet,100 g concentrate mixed with 150 g *Azolla pinnata*, which counted (12.40%). The lowest monocyte value (12.08%) was calculated in control group A, which received no *Azolla pinnata* supplementation. Statistically no significate (P>0.05) was observed.

Table 14: Monocytes (%) of post weaned goat kids under intensive management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
90th Day	12.08%[c]	12.40%[b]	12.75%[a]
LSD	0.141		
SE±	0.062		
P-value	0.07		

Effect of different levels of *Azolla pinnata* supplementation on platelets count (x10³/µL) of post weaned goat kids under intensive management system

Results of the table 15 reveals that the average platelet count (414.25 × 10³/µL) was recorded in the group C fed basal diet, 150 g concentrate mixed with 250 g *Azolla pinnata* daily, followed by group B receiving basal diet, 100 g concentrate mixed with 150 g *Azolla pinnata*, which showed a count of (368.75 × 10³/µL). Control group A, which received no *Azolla pinnata*, exhibited the lowest platelet count (346.25 × 10³/µL). Statistically no significate (P>0.05) was observed.

Table 15: Platelets count (x10³/µL) of post weaned goat kids under intensive management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
90th Day	346.25×10³/µL[c]	368.75×10³/µL[b]	414×10³/µL[a]
LSD	55.36		
SE±	24.47		
P-value	0.05		

Effect of different levels of *Azolla pinnata* supplementation on total serum protein (g/dl) of post weaned goat kids under intensive management system

Results of table 16 show that the average total serum protein concentration, with a mean value of 6.00 g/dl. This was followed by group B supplemented with basal diet, 100 g concentrate mixed with 150 g *Azolla pinnata*, which recorded total serum protein concentration of 5.84 g/dl. The control group A, which received no *Azolla pinnata*, exhibited the lowest total serum protein concentration at 5.50 g/dl. Statistical analysis showed that these differences were not significant (P>0.05).

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Table 16: Total serum protein (g/dl) of post weaned goat kids under intensive management system

Days	Groups		
	A (Control)	B (Treatment)	C (Treatment)
90th Day	5.50 g/dl[c]	5.84 g/dl[b]	6.00 g/dl[a]
LSD	0.63		
SE±	0.197		
P-value	0.24		

DISCUSSION

Investigating the effects of different inclusion levels of *Azolla pinnata* in the diet on the growth and performance, as well as the blood parameters, of goat kids raised under an intensive management system, represents an area of considerable interest to researchers engaged in livestock nutrition and management practices. In terms of its impact on productivity and health in livestock animals, *Azolla pinnata* is an attractive candidate because of its high protein content and ease of availability and representative of an inexpensive, readily cultivated source for feed for goats.

To maximize the contribution of *Azolla pinnata* to goat nutrition, this study will identify which levels are optimal for use in goat feeding programs and will provide greater understanding of the contribution of *Azolla pinnata* to improved growth and health of goats from smallholder farmers who rely on intensive goat production as their primary means of economic sustenance. In particular, the results of this study could provide valuable direction and insights for sustainable livestock management practices. The goat is an important part of rural household economies in the livestock industry in Pakistan, where goats account for approximately 37 per cent of the total ruminant population (Khan & Ashfaq, 2018). In addition, the work on *Azolla pinnata* will have relevance to developing countries because of its rapid growth cycle and high-quality feed source; the amino acids, crude protein and bioactive compounds, all of which are essential for goat nutrition, make it a suitable plant to use in livestock production systems, particularly for intensive goat production (Kathirvelan et al., 2015).

Group C had the greatest average weight gain during the trial, growing from an initial 9.00 kg to 17.50 kg by day 90. This is a sign that using *Azolla pinnata* as a supplement may be effective for increasing growth rate in sheep. The improved growth rate can likely be traced to the high amount of protein (20% to 30%) in the Azolla plant and the presence of essential amino acids and biopolymers (Reddy et al., 2011; Chatterjee et al., 2012). For growing sheep, *Azolla pinnata* can replace up to 6% of the diet's linseed cake and not have a negative impact on the growth rate. Nutritionally, these components can lead to higher digestibility of feed, greater assimilation of nutrients and larger metabolic activity, which can promote better growth (Ahmed et al., 2015). According to Dev et al. (2022), however, supplementation with *Azolla pinnata* that has been sun-dried does improve the performance of Sirohi goats without affecting their health or voluntary feed intake. Moreover, Sankar et al. (2021), show improvement of growth rate in Mecheri lambs through the addition of *Azolla pinnata* to their diets. The increase in growth rate in lambs appears to be due to the high levels of crude protein and minerals in *Azolla pinnata*. Daily weight gain and total weight gain were highest in the treatment group according to (Kumar et al., 2015; Madavi et al., 2019). Evaluate the results of studies that investigated the effect on Barbari goats of partially substituting concentrate mixtures for sun-dried Azolla. Partial replacement investigate date mixtures with sun-dried Azolla resulted in a gain in body weighing for Barbari goats. Daily supplementation with

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Azolla pinnata also resulted in improved growth performance when given at 10% or 20% levels to growing goats. Improved rates of gain were observed in Awassi lambs when replacing crude protein from concentrations for young lambs when *Azolla pinnata* was used at 2%, 4%, 8% and 12% levels. Incorporation of Azolla sp. into diets has also been associated with improved feed conversion rates and weight gains in other breeds such as Kamaruddin goats. Shital et al. (2012) report an average total gain of 6.70 kg for Osmanabadi goat kids fed diets with 15% Azolla meal.

Goat kids from group C experienced maximal morphometric measurements on day 90 of the study to include: body length (55.88 cm), height at withers (59.69 cm), and chest girth (55.88 cm) when compared to kids from groups B & A. These outcomes add further evidence to the effectiveness of *Azolla pinnata* to facilitate overall growth and morphological development in goat kids reared in an intensive feeding system. Statistical treatment via ANOVA to justify the first objective indicates that *Azolla pinnata* can be used as an effective protein source (Nayel et al., 2025) resulting in improved body weight, heart girth, height, and length. These data are consistent with the work of Chatterjee et al. (2013), who identified Azolla as a potential remedy to aid in alleviating the shortage of green fodder. The observed dose dependent increases in morphometric measurements resulted from the combination of a basal diet, 150 g of concentrate mixed with 250 g of Azolla, whereas group B received a basal diet, 100 g of concentrate mixed with 150 g of Azolla per day and control group A received only a basal diet likely due to improved amino acid composition, especially lysine, as well as greater availability of macronutrients for muscle/skeletal growth. The improvement in feed conversion efficiency over the 90-day trial may have contributed to these results.

The physiological and immunologic status of livestock can be determined from their hematological parameters (Kumar et al., 2022). Group C animals had the highest erythrocyte levels (0.435×10^6/µL) and mean corpuscular volume (MCV) (63 fL), both of which were significantly greater than Group A and Group B animals, indicating a greater oxygen transport ability, and providing an indication of improved immune ability and hematological status. Azolla (*Azolla pinnata*) can be used in diets for lambs as a partial component of corn silage up to 15% of the total diet without negative impacts on blood parameters and growth performance (Nayel et al., 2024). Concurrently, a replacement diet with 20.0% *Azolla pinnata* significantly increased feed efficiency and improved total protein and globulin plasma metabolites (Al-Suwaiegh, 2023). The increase in erythrocyte count and MCV in Group C may also be associated with the levels of vitamin B12, beta-carotene and iron in *Azolla pinnata* (Chatterjee et al., 2012).

Plasma protein was higher in goats fed 20 % Azolla compared to goats fed either 10 Azolla or a control diet (Kholif et al., 2019). Total leukocyte count (neutrophils, lymphocytes, monocytes) and platelet counts were not significantly affected (Tamang & Samanta, 1993). Total serum protein levels were all within the normal laboratory reference range as reported for healthy growing goats by (Kaneko, 1997).

The way *Azolla pinnata* supplementation significantly improves growth performance while maintaining stable hematological responses illustrates broader global trends seeking out sustainable/adaptive feeding strategies for livestock systems with limited resources. As developing countries face increasing losses in fodder availability, rising feed prices, and growing environmental regulations, the need for locally produced, nutrient-dense, inexpensive feed alternatives will continue to grow. Based on the nutritional properties of *Azolla pinnata*, it could be a viable candidate for use as a "commodity feed" due to its high protein (typically between 25 - 35%), essential amino acids, vitamins (including B12 and beta-carotene), and minerals (including iron, calcium, and phosphorus), which all support growth performance. However, *Azolla pinnata's* unique ability to buffer (or maintain) hematological responses to stressors means that its absolute size may not always accurately represent short-term shifts in growth due to its ability to maintain stable internal physiological parameters. These two phenomena (dramatic growth and stable internal parameters) are like the stock market, where the closing price reflects

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trends, but does not account for the volatility of intraday trading or the effect of external factors. Likewise, in biological trials, measuring growth at discrete timeframes (e.g., days 0 and 90) may mask short-term fluctuations caused by environmental stressors, diseases, or nutritional stresses. Despite this, numerous consistent investigations have reported that moderate levels of Azolla in ruminant livestock feed do not negatively affect the blood protein (hemoglobin) content or white blood cell (leukocytes) counts or other parameters of the blood. The review by El Naggar & El-Mesery. (2022) titled "*Azolla pinnata* as Unconventional
Feed & Fodder for Ruminants" showed that Azolla contains large amounts of protein, vitamins, and minerals. Animal trials indicate that incorporating Azolla into their diet results in improved average daily gains without causing changes in the animal's internal biochemical status.

CONCLUSIONS

The results of this study show that giving the basal diet and extra concentrate combined with Azolla pinnata for 90 days increased growth performance and several hematological status markers, such as erythrocytes (RBC) and mean corpuscular volume (MCV). Supplementing with concentration and Azolla did not appear to have any negative impact on any other hemogram parameters. In comparison to other treatment groups, group C (n=4), which was fed a basal diet plus 150 g concentrate and 250 g Azolla pinnata daily, continuously shown noticeably better growth performance and hematological parameters during the trial.

Author Contributions

IL is researcher and author of manuscript. SAT supervised study conducted. HR, GBK guided to conduct research in laboratory. JK, AR, NJ helped in formal analysis. AR, MA, MA and AM helped with manuscript writing review and editing.

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