

Growth and yield of intercrops under Drumstick (*Moringa oleifera*) based Agroforestry system

ABSTRACT

A field experiment on intercrops under Drumstick in Rabi season of 2020-2021 and 2021-2022 was carried out at experimental site in the Agroforestry field at Ranchi Veterinary College, Birsa Agricultural University, Ranchi, Kanke Ranchi district of Jharkhand, India which is the plain region of Chotanagpur plateau of Jharkhand. The experimental plots were laid out in randomized block design, sole farming and Moringa based Agroforestry system. Growth and yield attributes of like plant height, number of leaves, Plant population, No. of Primary branches, Length of siliqua, No. of seeds/siliqua, Total root length, Root tips 30 DAS, Days of 50% flowering, Days to 75% maturity were found higher in sole farming than when intercropped with Moringa in rabi season of 2020-21, 2021-22 and in pooled data. The yield characters of Rabi crops, such as grain yield, straw yield, biological yield and harvest index was maximum in Sole Wheat was 25.32, 23.17, 24.25 and 67.33, 68.14, 67.73 and 92.65, 91.32, 91.98 in 2020-21, 2021-22 and in pooled data respectively, while minimum in Moringa + Mustard, it was 6.16, 7.06, 6.61 and 15.01, 15.75, 15.38 and 21.17, 22.82, 21.99 in 2020-21, 2021-22 and in pooled data respectively.

Keywords: Moringa, Rabi, Intercropping, agroforestry system

1. Introduction

Agroforestry is a land use system, which integrates trees and shrubs on farmlands and rural landscapes to enhance productivity, profitability, diversity and ecosystem sustainability. Agroforestry not only provides environmental services, but also economic gains, as about 65 percent of the country's timber requirement is met from the trees grown outside forests ^[14]. At present agroforestry meets almost half of the demand of fuel wood, two third of small timber, 70-80% plywood, 60% paper and 9-11% green fodder requirement of livestock, besides meeting the subsistence needs of households for food, fruit, fibre, medicine, timber etc. ^[7]. Agroforestry can also reduce risks by having appropriate trees (species, age, diversity, management) at strategic locations at hillslope and landscape scale ^[15]. The mineral packed, vitamin rich, nutritious vegetable called the Miracle tree or drumstick or horse radish tree or West Indian Ben is botanically *Moringa oleifera* Lam. Lam. This is the most economically important species among the 12 species that belongs to the family

Moringaceae ^[11]. The name drumstick derives from the shape of the pod, resembling the slender and curved stick used for beating the drum. Probably the name radish tree originates from the pendulous, slender and thin shape of the immature fruits of the tree resembling very much the siliqua of the radish. The tree is indigenous to North West India and is well known for its multipurpose attributes, wide adaptability and ease of establishment. Moringa is mainly cultivated as pure plantations on upland conditions with plenty of sunshine and no water stagnation on a large scale. It has a large tap root and few lateral roots so it will not compete for nutrients with the crops. It also adds nutrients soil as it produces many protein rich leaves. They grow very quickly but do not provide too much shade due to the structure of their branches and leaves. They are also very good at reclaiming marginal land. Spacing depends on the type of soil and end-use of plant, the recommended spacing is 3m x 3m while for intensive production of green matter it can be densely seeded (100 seeds / m²). Moringa can be intercropped with maize, millet, sunflower

and other field crops. But the information on their compatibility as intercrops is still lacking. Hence the objective of this work was to evaluate the growth and yield of different intercropping systems with moringa, in wet and dry seasons, and found the best system for the ecological condition of Jharkhand state in India. With this background, project was initiated in 2018 in Birsa Agricultural University, Kanke, Ranchi (Capital district of Jharkhand) with the aim of developing agroforestry system for eastern plateau and hill that this study be designed to evaluate the influence of *Moringa oleifera* on the growth and yield of different Rabi crops – Wheat (*Triticum aestivium*), Mustard(*Brassica juncea*), Chickpea (*Cicer arietinum*) and different Kharif crops – Finger millet (*Eleusine coracana*), Soybean (*Glycine max*), Ground nut (*Arachis hypogaea*) intercrop in eastern plateau and hill condition of eastern India. If found encouraging, farmers would be advised to adopt and introduce Moringa in their cropping systems, emphasizing the numerous benefits of plant, particularly its potential to increase farm income. Therefore, an attempt has been made to explore the prospects of growing intercrops in *Moringa oleifera* to boost income under agroforestry system.

2. Materials and Methods

A two year field experiment was conducted during kharif and rabi season of 2020-21 and The experiment was conducted in the Agroforestry field at Ranchi Veterinary College, Birsa Agricultural University, Ranchi, Kanke Ranchi district of Jharkhand, India which is the plain region of chotanagpur plateau of Jharkhand. It is situated at a distance of about 3.5 km east. Ranchi is situated between 23°30' and 23°40' north latitudes and 85°30' and 85°40' east longitudes with an elevation of around 651 m from mean sea level and the district covers an area of 5097 km².

It is the eastern section of the Deccan plateau and comes under Central and North-Eastern Plateau (Sub Zone-IV), a part of agro-climatic (Zone VII) of the country known as

Eastern Plateau and Hill Region. The whole field was laid out as per plan to evaluate the influence of *Moringa oleifera* on the growth and yield of different Rabi crops – Wheat (*Triticum aestivium*), Mustard (*Brassica juncea*), Chickpea (*Cicer arietinum*) and different Kharif crops – Finger millet (*Eleusine coracana*), Soybean (*Glycine max*), Ground nut (*Arachis hypogaea*) intercrop under Moringa based agroforestry system and sole farming systems in eastern plateau and hill condition of eastern India. The experiment design adopted was randomized block design (RBD) with seven treatments and three replications in both the seasons. They were: T1: Moringa+ Wheat - Groundnut, T2: Moringa + Chickpea – Fingermillet, T3: Moringa + Mustard - Soybean, T4: Sole Moringa, T5: Sole Wheat - Groundnut, T6: Sole Chickpea – Fingermillet, T7: Sole Mustard - Soybean. Plot size was 9m x 6m and the spacing of Moringa was 3m X 3m. Moringa seeds were transplanted in the experimental field on June, 2016 and intercropping conducted during kharif and rabi season of 2020-2021 and 2021-2022.

3. Results

Data on plant height (cm) recorded at 30, 60 and 90 days after sowing of Rabi intercrops under *Moringa oleifera* is presented in Table 1. The maximum plant height of intercrops at 30 DAS were recorded in treatment *M. oleifera* + *T. aestivium* (15.833cm, 17.200 cm, 16.517 cm) which were statistically *at par* with sole *T. aestivium* (15.200 cm, 17.200 cm, 16.200cm). Similarly, maximum plant height of intercrops at 60 DAS were recorded in treatment sole *B. juncea* (42.400cm, 41.227cm, 41.813 cm) which were statistically *at par* with *M. oleifera*+ *B. juncea* (41.367 cm, 41.100 cm, 41.233cm) and significantly higher over sole *C. arietinum* (22.100cm, 23.140cm, 22.620cm) in 2020-21, 2021-22 and pooled respectively. Similarly, maximum plant height of intercrops at 90 DAS were recorded in treatment *M. oleifera*+ *B. juncea* (80.100cm, 79.100cm, 79.600cm) which were statistically *at par* with sole *B. juncea* (77.100cm,

79.837cm, 78.837cm) .Similarly, maximum plant height of intercrops at 120 DAS were recorded in treatment sole *B. juncea* (115.400cm, 114.100cm, 114.750 cm) which were significantly higher over *M. oleifera* + *B. juncea* (103.867cm, 103.800cm, 103.833 cm) in 2020-21, 2021-22 and pooled respectively . Minimum plant height were recorded in treatment *M. oleifera* + *C. arietinum* (49.167cm, 50.570cm, 49.868cm) in 2020-21, 2021-22 and pooled respectively.

Data on Number of leaves recorded at 30 and 60 days after sowing of Rabi intercrops under *Moringa oleifera* is presented in Table 2. The maximum number of leaves per branches of intercrops at 30 DAS were recorded in treatment sole *T. aestivum*

(15.080, 15.493, 15.287. Similarly, maximum number of leaves per branches of intercrops at 60 DAS were recorded in treatment sole *T. aestivum* (43.153, 43.480, 43.317) which were significantly higher over *M. oleifera* + *T. aestivum* (40.643, 41.807, 41.225) in 2020-21, 2021-22 and pooled respectively. Similarly, maximum plant population of intercrops were recorded in treatment sole *T. aestivum* (186.667 m², 191.667 m², 189.167 m²) which were statistically *at par* with *M. oleifera* + *T. aestivum* (179.00 m², 184.333 m², 181.667 m²) and significantly higher over sole *C. arietinum*, *M. oleifera* + *C. arietinum*, sole *B. juncea* and *M. oleifera* + *B. juncea* in 2020-21, 2021-22 and pooled respectively.

Table-1: Comparative growth performance of Rabi intercrops under *Moringa Oleifera* (Plant height)

Treatment	Plant height (cm)											
	30 DAS			60 DAS			90 DAS			120 DAS		
	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled
Moringa + Wheat	15.833 ^a	17.200 a	16.517a	40.333ab	38.600b	39.467b	70.760b	69.137b	69.948b	86.343d	90.393c	88.368d
Moringa + Chickpea	8.433c	8.267c	8.350c	20.433c	20.437d	20.435d	29.000c	27.507d	28.253d	49.167e	50.570e	49.868f
Moringa + Mustard	12.067b	13.567b	12.817b	41.367a	41.100a	41.233ab	80.100a	79.100a	79.600a	103.867b	103.800b	103.833b
Sole Moringa	-	-	-	-	-	-	-	-	-	-	-	-
Sole Wheat	15.200a	17.200a	16.200a	37.767b	41.247a	39.507b	69.700b	67.467b	68.583b	94.667c	92.300c	93.483c
Sole Chickpea	9.167c	9.367c	9.267c	22.100c	23.140c	22.620c	33.067c	32.133c	32.600c	53.200e	57.567d	55.383e
Sole Mustard	13.467b	14.567ab	14.017b	42.400a	41.227a	41.813a	77.100a	79.837a	78.468a	115.400a	114.100a	114.750a
SEm±	0.792	2.104	0.782	3.496	1.825	1.428	6.465	1.582	1.986	11.798	12.811	6.301
CD (p=0.05)	1.619	2.639	1.608	3.401	2.457	2.174	4.626	2.288	2.563	6.248	6.511	4.566
CV	7.199	10.857	6.875	5.488	3.939	3.496	4.241	2.124	2.365	4.100	4.221	2.978

Table-2: Number of leaves of Rabi intercrops under *Moringa Oleifera* Agroforestry System

Treatment	Number of leaves per branches								
	30 DAS			60 DAS			Plant Population (m ²)		
	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled
Moringa + Wheat	12.770b	15.083a	13.927b	40.643b	41.807b	41.225b	179.000a	184.333a	181.667a
Moringa + Chickpea	7.073cd	8.000b	7.537c	10.333c	10.333c	10.333c	30.333b	31.333b	30.833b
Moringa + Mustard	5.607e	5.993d	5.800d	8.403d	9.690c	9.047d	26.147b	30.147b	28.147b
Sole Moringa	-	-	-	-	-	-	-	-	-
Sole Wheat	15.080a	15.493a	15.287a	43.153a	43.480a	43.317a	186.667a	191.667a	189.167a
Sole Chickpea	7.667c	7.667bc	7.667c	10.000c	10.000c	10.000c	34.333b	35.333b	34.833b
Sole Mustard	5.977de	6.197cd	6.087d	9.433cd	10.460c	9.947c	29.147b	33.147b	31.147b
SEm±	0.418	0.744	0.304	0.326	0.470	0.153	22.968	26.105	23.576
CD (p=0.05)	1.176	1.569	1.004	1.039	1.248	0.712	8.718	9.295	8.833
CV (%)	7.162	8.857	5.879	2.809	3.272	1.896	5.921	6.059	5.876

Data on Number of Primary Branches of Rabi intercrops under *Moringa Oleifera* Agroforestry System is presented in Table 3. The maximum Number of primary branches of intercrops were recorded in treatment sole *T. aestivium* (4.700, 4.817, 4.758) which were statistically *at par* with *M. oleifera* + *T. aestivium* (4.233, 4.467, 4.350) and significantly higher over sole *B. juncea* (3.470, 3.637, 3.553) in 2020-21, 2021-22 and pooled respectively. Minimum Number of branches were recorded in treatment *M. oleifera* + *C. arietinum* (2.983, 2.733, 2.858) in 2020-21, 2021-22 and pooled respectively. Maximum Length of siliqua (cm) of intercrops were recorded in treatment sole *B. juncea* (5.353cm, 5.710cm, 5.532cm) which were significantly higher over sole *T. aestivium* (4.770cm, 4.800cm, 4.785cm) in 2020-21, 2021-22 and pooled respectively. Similarly, maximum Number of seeds/siliqua of intercrops were recorded in

treatment *M. oleifera* + *T. aestivium* (17.540, 17.453, 17.497) which were significantly higher over sole *T. aestivium* (16.073, 16.037, 16.055) in 2020-21, 2021-22 and pooled respectively

Data on Root length per plant of different Rabi crops under *Moringa Oleifera* Agroforestry System is presented in Table 4. The maximum total root length of intercrops were recorded in treatment sole *C. arietinum* (108.667, 102.333, 105.500) which were statistically *at par* with sole *T. aestivium* (93.400, 96.333, 94.867) and significantly higher over *M. oleifera* + *C. arietinum* (85.267, 87.667, 86.467) in 2020-21, 2021-22 and pooled respectively. Similarly, maximum root tips at the interval of 30 DAS of intercrops were recorded in treatment sole *T. aestivium* (62.00, 73.333, 67.667) which were statistically *at par* with *M. oleifera* + *C. arietinum* (56.667, 60.667, 58.667).

Table-3: Number of Primary Branches of Rabi intercrops under *Moringa Oleifera* Agroforestry System

Treatment	Number of primary branches			Length of siliqua (cm)			Number of seeds / siliqua		
	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled
Moringa + Wheat	4.233a	4.467a	4.350a	4.410b	4.733b	4.572b	17.540a	17.453a	17.497a
Moringa + Chickpea	2.943b	3.117c	3.030c	2.900c	2.833c	2.867c	1.567e	1.867e	1.717e
Moringa + Mustard	2.967b	3.147bc	3.057c	4.710b	5.017b	4.863b	9.843d	12.480d	11.162d
Sole Moringa	-	-	-	-	-	-	-	-	-
Sole Wheat	4.700a	4.817a	4.758a	4.770b	4.800b	4.785b	16.073b	16.037b	16.055b
Sole Chickpea	2.983b	2.733c	2.858c	2.750c	2.867c	2.808c	1.833e	1.933e	1.883a
Sole Mustard	3.470b	3.637b	3.553b	5.353a	5.710a	5.532a	11.957c	13.523c	12.740c
SEm±	0.087	0.074	0.057	0.062	0.067	0.042	0.643	0.239	0.316
CD (p=0.05)	0.536	0.495	0.436	0.452	0.470	0.372	1.459	0.890	1.023
CV (%)	8.297	7.445	6.653	5.985	5.974	4.831	8.183	4.639	5.525

Table-4: Root length per plant of different Rabi crops under *Moringa Oleifera* Agroforestry System

	Total root length			Root tips 30 DAS		
	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled
Moringa + Wheat	48.367 ^c	54.000b	51.183c	34.667b	37.333cd	36.000bc
Moringa + Chickpea	85.267b	87.667a	86.467b	56.667a	60.667ab	58.667a
Moringa + Mustard	31.170d	40.000bc	35.585d	17.667b	25.000d	21.333c
Sole Moringa	-	-	-	-	-	-
Sole Wheat	93.400ab	96.333a	94.867ab	62.000a	73.333a	67.667a
Sole Chickpea	108.667a	102.333a	105.500a	58.000a	48.000bc	53.000ab
Sole Mustard	35.913cd	37.667c	36.790cd	23.000b	28.333d	25.667c
SEm±	74.346	77.367	68.544	97.900	97.322	94.464
CD (p=0.05)	15.670	16.001	15.061	18.00	17.946	17.681
CV (%)	12.832	12.626	12.104	23.558	21.708	22.230

Data on Days of 50% flowering and 75% pod maturity in different Rabi intercrops under *Moringa Oleifera* Agroforestry System. The maximum Days to 50% flowering intercrops were recorded in treatment M. oleifera + B. juncea (53.217, 53.627, 53.422) which were statistically at

par with sole *B. juncea* (50.847, 51.480, 51.163) and significantly higher over sole *C. arietinum* (43.000) in 2020-21 and 2021-22 and pooled it were recorded significantly higher in treatment sole *T. aestivum* respectively. Maximum Days to 75% maturity of intercrops were recorded in

treatment sole *B. juncea* (96.097, 95.990, 96.043) which were statistically *at par* with *M. oleifera* + *B. juncea* (95.147, 96.483, 95.815) and significantly higher over *M.*

oleifera + *T. aestivum* (90.610, 91.443, 91.027) in 2020-21, 2021-22 and pooled respectively.

Table-5: Days of 50% flowering and 75% pod maturity in different Rabi intercrops under Moringa Oleifera AFS

Treatment	Days to 50% flowering		Pooled	Days to 75% maturity		Pooled
	2020-2021	2021-2022		2020-2021	2021-2022	
Moringa + Wheat	49.000a	45.333bc	47.167b	90.610cd	91.443	91.027c
Moringa + Chickpea	42.600b	42.667cd	42.633c	91.933bc	95.667	93.800b
Moringa + Mustard	53.217a	53.627a	53.422a	95.147ab	96.483	95.815ab
Sole Moringa	-	-	-	-	-	-
Sole Wheat	48.000ab	45.667b	46.833b	90.040cd	89.333	89.687c
Sole Chickpea	43.000b	41.000d	42.000c	87.767d	91.000	89.383c
Sole Mustard	50.847a	51.480a	51.163a	96.097a	95.990	96.043a
SEm±	9.567	2.441	4.340	3.295	1.163	1.369
CD (p=0.05)	5.627	2.842	3.790	3.302	1.962	2.129
CV (%)	6.474	3.351	4.413	1.975	1.155	1.263

Data on Grain yield (q ha^{-1}), stover yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index (%) of intercrops and sole crops under Moringa based agroforestry system is presented in Table 6. The grain yield in intercrops followed the order: Wheat > Chickpea > Mustard both under sole cropping and under intercropping. Among the treatments, the grain yield of intercrops was maximum under Sole Wheat (25.32 q ha^{-1} , 23.17 q ha^{-1} and 24.25 q ha^{-1}). The stover yield of intercrops was also higher under sole Wheat (67.33 q ha^{-1} , 68.14 q ha^{-1} and 67.73 q ha^{-1}) which was *at par* with Moringa + Wheat (66.38 q ha^{-1} , 66.42 q ha^{-1} and 66.40 q ha^{-1}). Likewise, the biological yield of intercrops was also maximum under sole Wheat (92.65 q ha^{-1} , 91.32 q ha^{-1} and 91.98 q ha^{-1}) which was *at par* with Moringa + Wheat (91.23 q ha^{-1} , 88.04 q ha^{-1} and 89.63 q ha^{-1}). However, the harvest index of intercrops was found higher in case of Moringa + Chickpea (38.51%, 39.38% and 38.95%) which was *at par* with sole chickpea (37.12%, 37.97% and

37.54%), followed by sole Mustard (29.83%, 31.09% and 30.46%) in 2020-21, 2021-22 and in pooled data respectively.

Data on Wheat equivalent yield (q ha^{-1}) of intercrops and sole crops under Moringa based agroforestry system is presented in Table 6. The Wheat equivalent yield in intercrops followed the order: Wheat > Chickpea > Mustard both under sole cropping and under intercropping. Among the treatments, the Wheat equivalent grain yield of intercrops was maximum under sole Wheat (5.27 q ha^{-1} , 5.46 q ha^{-1} and 5.37 q ha^{-1}) which was *at par* with Moringa + Wheat (5.11 q ha^{-1} , 5.32 q ha^{-1} and 5.22 q ha^{-1}), followed by sole Chickpea (4.56 q ha^{-1} , 4.77 q ha^{-1} and 4.67 q ha^{-1}) in 2020- 21, 2021-22 and in pooled data respectively. Likewise, the Wheat pea equivalent biological yield of intercrops was also higher under sole Wheat (22.78 q ha^{-1} , 23.37 q ha^{-1} and 23.08 q ha^{-1}) which was statistically *at par* with Moringa + Wheat (21.79 q ha^{-1} , 22.50 q ha^{-1} and 22.15 q ha^{-1}), followed by sole Chickpea (17.66 q ha^{-1}), followed by sole Chickpea (17.66 q

ha⁻¹, 18.12 q ha⁻¹ and 17.89 q ha⁻¹) in 2020- 21, 2021-22 and in pooled data respectively.

Table-6: Grain yield (q ha⁻¹), stover yield (q ha⁻¹), biological yield (q ha⁻¹) and harvest index (%) of intercrops and sole crops under Moringa based agroforestry system

Treatment	Grain yield(q/ha)			Straw yield (q/ ha)			Biological yield (q/ha)			Harvest index (%)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Moringa + Wheat	24.84a	21.61b	23.23a	66.38a	66.42b	66.40	91.23a	88.04b	89.63b	27.22b	24.55c	25.89c
Moringa + Chickpea	11.97b	12.70c	12.34b	19.11b	19.54c	19.32	31.08b	32.24c	31.66c	38.51a	39.38a	38.95a
Moringa + Mustard	6.16c	7.06d	6.61c	15.01c	15.75d	15.38	21.17c	22.82d	21.99d	29.08b	30.97b	30.03b
Sole Moringa	-	-	-	-	-	-	-	-	-	-	-	-
Sole Wheat	25.32a	23.17a	24.25a	67.33a	68.14a	67.73	92.65a	91.32a	91.98a	27.29b	25.37c	26.33c
Sole Chickpea	12.08b	12.44c	12.26b	20.47b	20.27c	20.37	32.55b	32.72c	32.63c	37.12a	37.97a	37.54a
Sole Mustard	6.47c	7.57d	7.02c	15.23c	16.77d	16.00	21.70c	24.34d	23.02d	29.83b	31.09b	30.46b
SEm±	1.67	0.50	0.48	0.66	0.76	0.34	1.98	1.59	1.23	2.09	1.10	0.60
CD (p=0.05)	2.35	1.29	1.26	1.48	1.58	1.06	2.56	2.29	2.01	2.63	1.91	1.41
CV	8.93	5.04	4.86	2.40	2.53	1.71	2.91	2.60	2.28	4.59	3.33	2.47

Table-7: Wheat equivalent yield (q ha⁻¹) of intercrops and sole crops under Moringa based agroforestry system

Treatment	Wheat equivalent yield (q ha ⁻¹)								
	Grain yield(q/ha)			Straw yield (q/ ha)			Biological yield (q/ha)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Moringa + Wheat	24.84b	21.61b	23.23	66.38a	66.42a	66.40	91.23a	88.04a	89.63
Moringa + Chickpea	30.06a	31.90a	30.98	47.97c	49.05b	48.51	78.04c	80.95b	79.50
Moringa + Mustard	10.85c	12.45c	11.65	26.45d	27.75c	27.10	37.31d	40.20c	38.75
Sole Moringa									
Sole Wheat	25.32b	23.17b	24.25	67.33a	68.14a	67.73	92.65a	91.32a	91.98
Sole Chickpea	30.33a	31.24a	30.78	51.40b	50.90b	51.15	81.73b	82.14b	81.94
Sole Mustard	11.41c	13.34c	12.37	26.83d	29.55c	28.19	38.24d	42.89c	40.57
SEm±	2.39	2.64	0.52	1.51	1.57	0.41	3.26	6.53	0.73
CD (p=0.05)	2.81	2.95	2.70	2.24	2.28	2.11	3.28	4.65	3.77
CV	6.98	7.29	7.14	2.58	2.57	2.57	2.58	3.60	3.14

4. Discussion

The results presented in above section, the plant population, plant height as well as number of leaves of Rabi crops under sole farming system was higher than Moringa based agroforestry system. Pervin et al. (2015) ^[13] reported that the plant height of mustard in association with Kalokoroi tree, gradually decreased toward the tree base which may be due to competition for nutrient and water between the root system of mustard and Kalokoroi tree. Root length and root hairs were affected by Moringa trees at all the growth stages of mustard and among different treatments, longer root length was observed under sole farming system. Thus, there was reduction in root length in agroforestry system as compared to sole farming system. Bibyan et al. (2020) ^[3] reported that the root length, stem diameter, root weight and number of plants per m² of Indian mustard increased significantly at 4 meters away from the Khejri tree. Mirjha (2016) ^[10] reported that the Mango+Cowpea-Mustard cropping system exhibited significantly higher CGR between different growth duration over rest of cropping systems. Similarly results also found that by Mohsin et al. (2021) ^[12] reported that in mustard primary branches per plant and seeds per siliqua were at par under Eucalyptus, Poplar, and sole cropping. Yield attribute viz. length of siliqua, number of seeds per siliqua and test weight of intercrops was affected by Moringa trees at all the growth stages of mustard, and the maximum was observed under sole farming system as compared to Moringa based agroforestry system. This may be attributed to cumulative effect of partial shade and competition for moisture and different nutrients between the root system of intercrops and Moringa tree. Similar results were reported by a number of other researchers (Basak et al., 2011; Farhana et al., 2013; Kundu et al., 2014; Divya et al., 2018; Bibyan et al., 2020) ^[2, 6, 19, 5, 3]. Yield of intercrops like grain yield, straw yield, biological yield and harvest index affected by Moringa tree and maximum was observed under sole farming system as compared to

Moringa based agroforestry system. This may be attributed to cumulative effect of partial shade and competition for moisture and nutrients between the intercrops and Moringa tree. Similar results were found by a number of other researchers (Kumar and Nandal, 2004; Dhara and Sharma, 2015; Pervin et al., 2015; Divya et al, 2018; Ahlawat et al., 2019; Mohsin et al., 2021). ^[8, 4, 13, 5, 1, 12]

5. Conclusion

All the growth parameters, yield attribute and yield approximately were found better in sole farming system as compared to Moringa based agroforestry system in both the year (2020-21 & 2021-22). Among all the treatment, Sole Wheat was found better in term of productivity and lowest with Moringa tree were found in Moringa + Mustard due to cumulative effect of partial shade and competition for moisture and nutrients between the mustard and Moringa tree in 2020-21, 2021-22 and in pooled data respectively.

7. References

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