**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, emphasing 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.

1. **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.

1. **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. aestivium* (15.080, 15.493, 15.287. Similarly, maximum number of leaves per branches of intercrops at 60 DAS were recorded in treatment sole *T. aestivium* (43.153, 43.480, 43.317)which were significantly higher over *M. oleifera + T. aestivium* (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. aestivium* (186.667 m2, 191.667 m2, 189.167 m2)which were statistically *at par* with *M. oleifera + T. aestivium* (179.00 m2, 184.333 m2, 181.667 m2*)* andsignificantly higher oversole *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** | 15.833a | 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 (m2)** | | |
| **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 oversole *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** | 48.367c | 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. aestivium* 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. aestivium* (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, 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.

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