LAPORAN
PENELITIAN *PROFESSORSHIP*
UNIVERSITAS LAMPUNG

PENGEMBANGAN TEKNOLOGI PIROLISIS BIOMASA LIMBAH JAGUNG UNTUK MENGHASILKAN BIOCHAR PEMBENAH TANAH

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PROGRAM STUDI TEKNIK PERTANIAN
FAKULTAS PERTANIAN
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2021

HALAMAN PENGESAHAN LAPORAN PENELITIAN
SKEMA PROFESSORSHIP - UNIVERSITAS LAMPUNG

Judul	: Pengembangan Teknologi Pirolisis Biomasa Limbah Jagung Untuk Menghasilkan Biochar Pembenah Tanah
Manfaat sosial ekonomi	: Pengembangan Ilmu Pengetahuan dan Teknologi
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Lama Kegiatan	: 6 bulan
Biaya Kegiatan	: Rp.50.000.000,- (Lima puluh juta rupiah)

Sumber Dana	: a. Sumber Dana Institusi	: Rp.50.000.000,-
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RINGKASAN

Budidaya jagung dan aktivitas panen beserta pasca panen menghasilkan limbah biomassa dalam jumlah besar, yaitu batang jagung sekitar 1 ton/ha dan janggel sekitar 2 ton/ha. Sejauh ini penanganan limbah jagung adalah dengan cara dibakar. Pembakaran biomassa limbah jagung tidak hanya menghasilkan asap yang menggangu, tetapi juga membuang sumberdaya yang sangat berharga, yaitu karbon organik, ke atmosfer secara sia-sia. Pembakaran biomassa limbah jagung dapat dilakukan dengan cara yang lebih ramah dan berdaya guna dengan cara membatasi jumlah oksigen atau udara selama pembakaran sehingga terjadi pembakaran secara anaerobik atau pembakaran dengan oksigen yang sangat terbatas. Proses yang dinamakan pirolisis atau karbonisasi ini akan menghasilkan produk arang padat atau biochar yang dapat digunakan untuk berbagai keperluan. Selain sebagai bahan bakar dengan nilai energi yang tinggi (sekitar 30 MJ/kg), arang dapat dikembalikan ke lahan sebagai bahan pembenah tanah (soil amendment) dan akan menjadi sumber karbon selama bertahun-tahun. Dengan mengembalikan arang ke lahan akan tercipta suatu system budidaya jagung yang sirkuler sehingga lebih sustainable.

Penelitian ini bertujuan untuk mengembangkan teknologi pirolisis yang sesuai untuk diaplikasikan guna penanganan limbah jagung. Penelitian dilakukan dengan merancang kiln pirolisis janggel jagung. Kiln dirancang untuk mampu mengolah tongkol jagung minimal 5 ton sekali proses. Produk arang (biochar) yang dihasilkan akan dianalisis karakteristiknya yang meliputi kadar air, kadar abu, nilai kalori, daya serap air, dan berat jenis.

Hasil yang sudah diperoleh dari penelitian kiln pirolisis berukuran 3,5 m x 4,5 m dengan kedalaman 1,5 m dengan kapasitas sampai 7 ton tongkol jagung. Kiln sudah diuji dan hasilnya belum maksimal karena masih ada sebagian tongkol jagung yang belum terpirolisi. Biochar dari tongkol yang sudah terpirolisis digiling dan digunakan sebagai bahan pembenah (amendment) tanah pada budidaya tanaman jagung. Hingga laporan ini dibuat, tanaman jagung masih berumur 1 bulan. Secara terpisah, penggunaan biochar tongkol jagung sebagai bahan pembenah tanah juga dilakukan pada budidaya tanaman sawi. Penanaman dilakukan di dalam pot dengan ukuran tinggi 13 cm, diameter atas 19 cm dan diameter bawah 13,5 cm. Dosis *biochar* yang diaplikasikan sebanyak 90 g/pot atau 3% dari berat total media tanam. Hasil penelitian menunjukkan pengaruh *biochar* nyata pada taraf (P>5%) terhadap parameter pertumbuhan, berat brangkasan segar, produktivitas air dan produktivitas pupuk. Suhu pirolisis *biochar* yang optimal untuk pakcoy adalah pada suhu 350°C, dengan hasil rata-rata bobot brangkasan atas segar 30,6 gram, bobot total 39,36 gram, dan produktivitas pupuk 35,06%. Kombinasi *biochar* dan dosis pupuk urea terbaik terhadap pertumbuhan dan produktivitas tanaman pakcoy yaitu B2P1.

Luaran yang ditargetkan dari penelitian ini adalah teknologi tepat guna berupa kiln pirolisis kapasitas 7 ton tongkol jagung dengan tingkat kesiapterapan (TKT) level 6 yang telah didemonstrasikan di lokasi mitra. Selain itu, sebuah paper telah disubmit ke jurnal internasional Q3 (Journal of Agriculture and Rural Development in the Tropics and Subtropics)

BAB 1. PENDAHULUAN

1.1. Latar Belakang

Tanaman jagung merupakan tanaman pangan lahan kering kedua di Lampung setelah singkong. Jagung dipanen pada umur 100-120 hari tergantung kebutuhan. Pemanenan jagung menghasilkan limbah batang jagung di lahan. Batang jagung yang masih hijau dapat digunakan sebagai pakan ternak, tetapi biasanya masih tersisa banyak di lahan. Setelah kering batang jagung dibabat lalu disusun memanjang di lahan sebagai mulsa. Masalahnya, tumpukan batang jagung ini akan perlu waktu lama untuk membusuk. Beberapa petani akan membakar tumpukan batang jagung di lahan. Abunya bermanfaat bagi tanah. Tetapi sebagian besar karbon akan hilang selama pembakaran sehingga tidak kembali ke lahan.

Dari kegiatan pasca panen juga dihasilkan limbah berupa janggel jagung. Janggel jagung bisa dikomposkan untuk menghasilkan pupuk organik yang baik. Tetapi pengomposan janggel memerlukan waktu lama (1 tahun). Oleh karena itu, petani biasanya membakar janggel jagung di sekitar rumah. Hal ini akan menimbulkan asap tebal yang mengganggu. Selain itu, semua karbon hanya akan terbang ke atmosfer sebagai CO_2. Gambar 1 memperlihatakan penanganan limbah jagung di masyarakat saat ini. Penanganan limbah jagung dapat ditingkatkan melalui teknologi sederhana yang lebih ramah lingkungan, yaitu proses pirolisis atau karbonisasi.

Gambar 1. Penanganan biomassa limbah jagung saat ini: Jagung siap panen (tengah), Batang jagung ditumpuk dalam barisan memanjang (kiri atas), Batang jagung dibakar di lahan (kiri bawah), Janggel jagung dibakar (kanan bawah), Kompos janggel setelah 1 tahun (kanan atas).

Pirolisis merupakan proses pembakaran tanpa udara atau oksigen untuk menghasilkan produk padat berupa arang atau biochar. Sedikit oksigen masih bisa ditolerir sepanjang tidak menimbulkan proses gasifikasi. Pirolisis juga menghasilkan produk cair berupa asap cair atau cuka kayu yang memiliki aroma khas dan dapat digunakan sebagai bahan pengawet. Arang hasil produksi pirolisis dapat digunakan sebagai bahan bakar dengan nilai kalori yang cukup tinggi mencapai sekitar 30 MJ/kg. Arang janggel juga dapat digunakan sebagai pembenah tanah untuk meningkatkan produktivitas tanah. Arang memiliki luas permukaan yang besar sehingga memiliki kapasitas penyimpanan yang tinggi terhadap unsur hara. Nutrisi yang diberikan melalui pemupukan akan bertahan lebih lama jika tersimpan di dalam arang. Arang juga bagus sebagai rumah bagi mikroorganisme tanah yang akan meningkatkan dekomposisi di dalam tanah.

Persoalannya adalah bahwa limbah jagung terkonsentrasi di dua lokasi. Batang jagung terkonsentrasi di lahan, sedangkan janggel jagung di sekitar rumah atau lokasi pemipilan jagung. Hal ini menuntut tungku pirilisis yang berbeda. Pirolisis di lahan dapat dilakukan secara sederhana dengan tungku lubang tanah. Sedangkan tungku pirolisis di sekitar rumah harus dikembangkan agar fleksibel dan mampu menangani limbah janggel yang ada.

1.2. Tujuan Penelitian

Penelitian ini bertujuan untuk: 1) Merancang tungku pirolisis yang aplikatif bagi petani baik di lahan maupun di rumah, 2) Menguji tungku pirolisis untuk memproduksi arang dari tongkol jagung di sekitar rumah dan pirolisis batang jagung di lahan, dan 3) Melakukan karakterisasi arang yang untuk mengetahui kualitas dan potensi pemanfaatan arang limbah jagung.

Penelitian ini sangat urgen mengingat umur tanaman jagung yang cukup singkat. Penanganan limbah yang cepat dan bermanfaat multiguna diperlukan untuk mencegah timbunan limbah jagung. Jika arang yang dihasilkan diaplikasikan sebagai bahan pembenah tanah, akan tercipta sistem budidaya jagung yang lebih *sustainable*. Temuan yang dihasilkan berupa teknologi tungku pirolisis diharapkan menjadi cara penanganan limbah jagung yang lebih ramah lingkungan. Jika arang yang dihasilkan digunakan sebagai bahan pembenah tanah oleh masyarakat petani, maka akan tercipta suatu sistem budidaya yang lebih *sustainable*. Teknologi pirolisis limbah jagung akan memberikan kontribusi bagi penanganan limbah jagung yang lebih ramah lingkungan.

BAB 2. TINJAUAN PUSTAKA

2.1. Limbah Panen dan Pascapanen Jagung

Jagung merupakan salah tanaman pangan yang dibudidayakan di lahan kering. Di Provinsi Lampung, jagung menjadi pilihan petani setelah singkong. Pada tahun 2017 luas tanaman jagung mencapai 482.607 ha dengan produksi 2.518.894 ton dan produktivitas 52.19 ton/ha (Badan Pusat Statistik Provinsi Lampung, 2018). Pada tahun 2019 produksi jagung di Provinsi Lampung sedikit mengalami penurunan menjadi 2.374.384 ton (Bidang Integrasi Pengolahan dan Diseminasi Statistik, 2020). Jagung dan singkong ditanam di lahan yang sama sehingga luas tanaman jagung akan berkejaran dengan singkong dan sangat ditentukan oleh harga kedua komoditas ini. Pada saat harga singkong tinggi, petani akan berbondong-bondong menanam singkong sehingga terjadi over supply dan menimbulkan harga singkong menjadi jatuh. Sebaliknya pada saat harga jagung bagus, petani menanam jagung sehingga produksi jagung berlebihan dan harganya jatuh.

Jagung dipanen pada umur 100-120 hari tergantung kebutuhan. Kegiatan pemanenan dan pasca panen (terutama pemipilan) jagung menghasilkan biomasa limbah berupa batang, daun, dan kulit yang tertinggal di lahan serta janggel dan jenjet yang dihasilkan dari pemipilan. Komposisi biomassa limbah jagung per satuan luas tanaman (ha) dapat dilihat pada Tabel 1. Secara keseluruhan, jumlah biomassa limbah jagung mencapai 3 ton/ha dengan komposisi sekitar 2 ton/ha janggel dan 1 ton/ha batang jagung (Yuliana, 2020).

Tabel 1. Komposisi biomassa limbah jagung (Yuliana, 2020)

Lokasi	Jenis limbah	Kuantitas (kg)*	Nilai energi (MJ/kg)
Lahan	Batang	864 (28,5)	15,66
	Daun	672 (22,2)	15,20
	Kulit (kelaras)	472 (15,6)	15,56
Pemipilan	Janggel	1.008 (33,3)	17,66
	Jenjet	10 (0,3)	17,22
TOTAL		3.026 (100)	

*Angka dalam kurung menyatakan persen berat dari total limbah.

2.2. Pengelolaan Biomassa Limbah Jagung

Saat ini sebagian besar biomassa limbah jagung (batang jagung dan janggel) masih dibuang atau dikelola dengan cara yang tidak baik. Jumlah limbah janggel berkisar antara 20 hingga 25% dari jagung bertongkol dan dipengaruhi oleh waktu panen. Jagung yang dipanen pada umur 100 hari masih belum begitu kering sehingga menghasilkan limbah janggel hingga 25%. Sedangkan jagung yang dipanen pada umur 120 hari sudah cukup kering dan menghasilkan janggel 20%. Janggel bisa digunakan sebagai bahan bakar sebagaimana kayu. Dalam kondisi yang belum kering pembakaran janggel akan menghasilkan asap tebal yang akan mengotori dapur. Pilihan yang paling banyak dilakukan oleh masyarakat petani dan pedagang penampung adalah membakar janggel jagung di sekitar rumah. Ini merupakan pilihan yang tidak ramah lingkungan. Pembakaran janggel akan menghasilkan asap tebal karena kadar air janggel masih tinggi. Sebagian besar pembakaran dilakukan di depan rumah atau di pinggir jalan sehingga dapat membahayakan pengguna jalan. Selain itu, pembakaran berarti membuang karbon ke atmosfer secara percuma. Padahal karbon mestinya dikembalikan ke lahan agar tercipta suatu system budidaya yang lestari. Janggel bisa dikomposkan dengan cara ditimbun dalam tanah. Tetapi, jumlah yang banyak dan lamanya waktu dekomposisi (lebih dari setahun), mengakibatkan teknologi ini pun tidak dipilih oleh masyarakat.

Limbah pemanenan jagung di lahan adalah batang jagung, yang masih hijau digunakan sebagai pakan ternak. Karena masa panen yang singkat dan belum tersedia teknologi pengawetan yang aplikatif, maka biasanya masih tersisa banyak di lahan. Setelah kering batang jagung dibabat lalu disusun memanjang di lahan sebagai mulsa. Masalahnya, tumpukan batang jagung ini akan perlu waktu lama untuk membusuk. Beberapa petani akan membakar tumpukan batang jagung di lahan. Abunya akan memberikan tambahan mineral yang baik. Tetapi sebagian besar karbon akan hilang selama pembakaran sehingga tidak kembali ke lahan.

2.3. Pirolisis Limbah Jagung

Pembakaran janggel jagung dan batang jagung sesungguhnya dapat dilakukan dengan cara yang lebih baik dan lebih ramah lingkungan melalui proses pirolisis. Pirolisis adalah dekomposisi termokimia bahan organik menjadi berbagai produk berguna (Kantarelis et al., 2013). Sebagian besar makalah menjelaskan pirolisis sebagai proses dengan atmosfir lembam tanpa adanya oksigen. Namun, oksigen terbatas diperbolehkan selama tidak memfasilitasi gasifikasi secara substansial (Basu, 2010; Mohan et al., 2006). Dari segi termal, proses pirolisis dapat dibagi menjadi empat tahap: pengeringan, tahap awal, tahap menengah, dan tahap akhir (Basu, 2010; Mazlan et al., 2015). Secara umum reaksi pirolisis dapat disajikan sebagai berikut:

$$\text{Biomassa} + \text{panas} \rightarrow \text{arang} + \text{cairan} + \text{gas} + \text{uap} \quad (1)$$

Awalnya, pirolisis adalah proses dengan laju pemanasan lambat dengan arang sebagai produk utamanya. Kini, pirolisis cepat telah dikembangkan untuk mendapatkan produk yang lebih cair. Pirolisis cepat memiliki laju pemanasan yang tinggi dan waktu tinggal yang sangat singkat (<2 detik) dan diikuti dengan kondensasi yang cepat (Balonek, 2011). Pada kondisi pirolisis cepat dengan laju pemanasan 1000 °C/s dan suhu pirolisis sekitar 500 °C akan dihasilkan 60–70% bio-oil, 15–25% biochar, dan 10–15% gas (Bridgwater et al., 1999).

Proses pirolisis limbah jagung menghasilkan produk padat berupa arang atau biochar yang dapat digunakan sebagai bahan bakar karena memiliki nilai kalori yang tinggi mencapai sekitar 30 MJ/kg. Arang janggel juga dapat digunakan sebagai pembenah tanah untuk meningkatkan produktivitas tanah. Arang memiliki luas permukaan yang besar sehingga memiliki kapasitas penyerapan yang besar terhadap unsur hara. Nutrisi yang diberikan melalui pemupukan bertahan lebih lama jika terserap ke dalam arang. Arang juga bagus sebagai rumah bagi organisme yang akan meningkatkan dekomposisi di dalam tanah.

2.4. Pengembangan Tungku Pirolisis

Proses pirolisis memerlukan tungku atau kiln. Jaman dahulu pirolisis kayu dilakukan dengan menggali tanah, menimbun kayu ke dalam lubang, menutupi kayu dengan tanah, lalu membakar tumpukan kayu. Dalam kondisi seperti ini akan tercipta pembakaran anaerobik atau dengan oksigen sangat terbatas dan menghasilkan arang. Saat ini ada beberapa jenis tungku pirolisis yang digunakan pada industry pembuatan arang, di antaranya adalah tungku kotak, tungku kubah, tungku kiln, dan tungku drum.

Tungku Kotak. Tungku kotak memiliki kapasitas volume yang cukup besar. Namun, waktu pengerjaan pada tungku ini relatif lebih lama. Desain tungku berbentuk kotak atau persegi memudahkan penumpukan kayu (Sulistyo *et al.*, 2017). Tungku kotak terbuat dari konstruksi bata dan tanah liat setebal ± 0,3m dengan dimensi ruang dalam 2 m (volume 8 m^3). Pada bagian atap tungku terdapat satu jendela untuk pembakaran awal dan penambahan kayu. Tiga titik lubang kecil pada bagian sisi badan tungku (kanan, belakang, dan kiri), berjarak vertikal ± 50 cm. Lubang ini untuk pengaturan suhu yang penting dilakukan karena dapat mempengaruhi penyusutan bahan baku dan nilai kalor (Tirono dan Sabit, 2011). Semakin tinggi suhu maka semakin tinggi pula penyusutan dan nilai kalornya.

Tungku Kubah. Tungku kubah umum digunakan pada skala komersial memiliki karena memiliki volume yang besar. Tungku kubah terbuat dari konstruksi bata dan tanah liat. Tungku Kubah terbagi menjadi dua bagian, yaitu badan dan kubah. Tungku kubah memiliki tebal ± 0,3 m, dimensi tinggi 3,8 meter (2 m tinggi badan, dan 1,8 m tinggi kubah) dan jari-jari 2 meter, dengan volume 41,68 m^3. Pada bagian kiri dan kanan kubah terdapat dua jendela tungku. Jendela ini berfungsi sebagai tempat pembakaran awal serta jalur untuk memasukkan tambahan bahan baku. Luas jendela tungku mencapai ±2,4 m^2. Rendemen arang dan komposisi produk asap cair sangat dipengaruhi oleh suhu (Ratnawati dan Hartanto, 2010).

Tungku Drum. Tungku drum banyak digunakan pelaku usaha arang karena murah, mudah, praktis, dan dapat dipindah (Mardiyanto dan Purnomo, 2016). Selain itu, proses pembakaran relatif cepat. Syahrinudin dkk (2018) menyebutkan tungku drum tertutup menghasilkan arang sempurna, tanpa abu dan sangat getas. Namun, tungku drum memiliki volume yang kecil dibandingkan menggunakan tungku kubah. Tungku drum memiliki tinggi 0,9 m dan jari-jari 0,29 m (volume 0,285 m^3). Tungku ini memiliki 4 lubang kecil yang terdapat di bagian bawah, tengah dan atas sisi drum dengan jarak vertical ± 20 cm. Fungsi lubang kecil adalah untuk pengaturan oksigen dan kontrol suhu pembakaran.

Limbah jagung terkonsentrasi di lahan (batang jagung) dan sekitar rumah (janggel). Oleh karena itu pengembangan tungku pirolisis perlu untuk mengakomodasi kondisi ini. Untuk pirolisis batang jagung dapat menggunakan tungku gali tanah. Sedangkan untuk pirolisis janggel bisa menggunakan tungku dari logam atau kombinasi logam dan lubang tanah. Tabel 2 menunjukkan roadmap penelitian yang terkait dengan pirolisis dan limbah jagung.

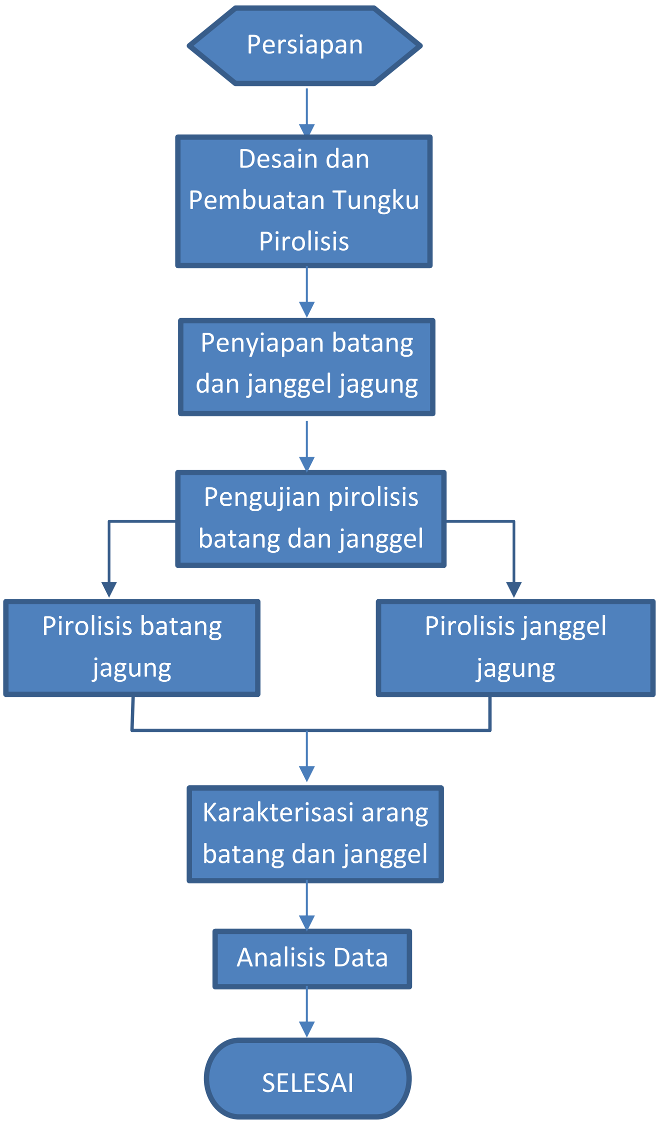
Tabel 2. Roadmap penelitian biochar

Tahun	Topik	Output
2016	Reaksi karbonisasi kayu (Wahyu Hidayat dkk)	Jurnal internasional (Qi et al., 2016)
2017	Karakteristik karbonisasi kayu muda Indonesia (Wahyu Hidayat dkk)	Jurnal internasional (Hidayat et al., 2017)
2018	Sifat fisik dan anatomi arang bamboo Indonesia (Wahyu Hidayat dkk)	Jurnal internasional (Park et al., 2018)
2019	Pembuatan Bahan Bakar Padat Setengah Arang Dari Tongkol Jagung	Skripsi, Jurusan TEP, Pembimbing Agus Haryanto (Arifin, 2019)
2020	Potensi energi dari limbah jagung	Skripsi, Jurusan TEP, Pembimbing Agus Haryanto (Yuliana, 2020)
2020	Karakteristik Arang Hayati dari Limbah Kayu Sengon dan Karet (Wahyu Hidayat dkk)	Prosiding Seminar Nasional Konservasi Sumberdaya Alam untuk Pembangunan Berkelanjutan, 21 April 2020.
2020	Karakteristik dan Aplikasi biochar kayu Shorea (Wahyu Hidayat dkk)	International Conference of Biomass and Bioenergy. Bogor, 10-11 August 2020.
2021	Kajian literature tentang pirolisis limbah kayu	Paper accepted di jurnal Energies (Q1) (Haryanto et al., 2021)
2021	Pengembangan teknologi pirolisis limbah jagung (diajukan)	Teknologi tepat guna dan paper pada jurnal Q3 dan Seminar Internasional

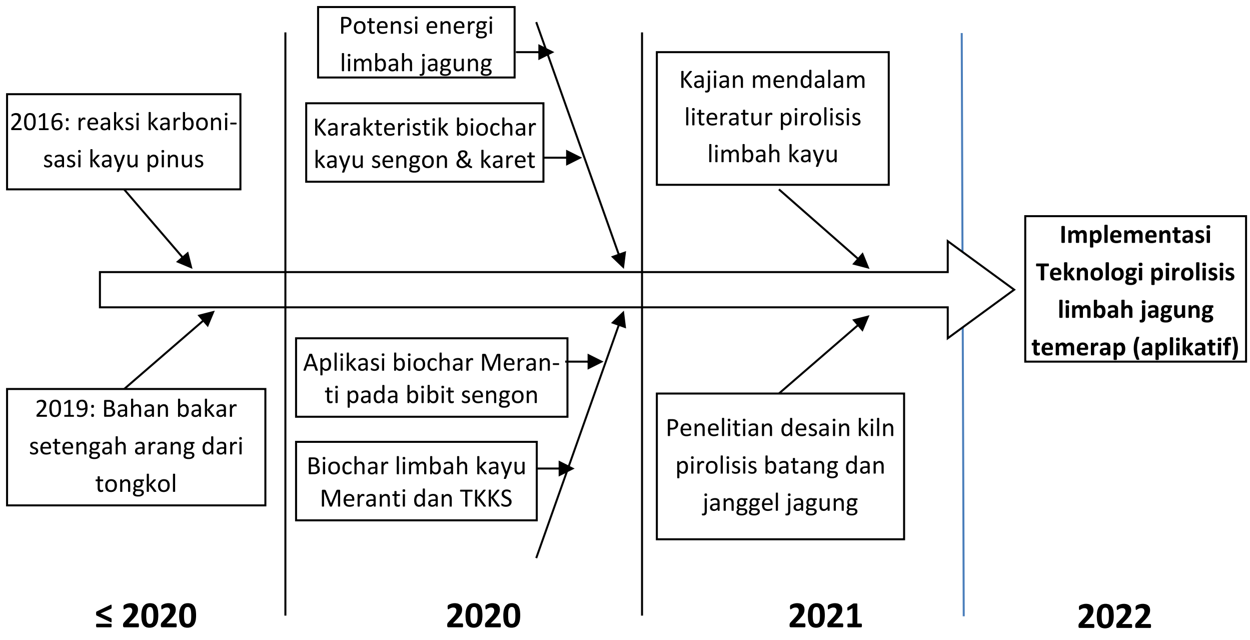
BAB 3. METODE PENELITIAN

3.1. Diagram Alir dan Roadmap

Penelitian dilakukan dengan mengikuti diagram bagan alir sebagaimana diberikan dalam Gambar 2. Penelitian mengenai pirolisis dan potensi energi limbah jagung sudah dilakukan sejak beberapa tahun oleh tim atau anggotanya. Secara keseluruhan penelitian untuk menghasilkan teknologi pirolisis limbah jagung yang temerap (aplikatif) ini direncanakan memerlukan waktu hingga 2 tahun lagi. Roadmap penelitian secara keseluruhan dapat dilihat pada Gambar 3.



Gambar 2. Diagram alir rencana penelitian pengembangan teknologi pirolisis limbah jagung.



Gambar 3. Roadmap penelitian pengembangan teknologi pirolisis limbah jagung

3.2. Pembuatan Tungku Pirolisis

Kiln untuk pirolisis janggel jagung akan mengadopsi kiln kotak. Dinding dibuat dari pasangan bata-semen yang diplester dengan lempung. Berdasarkan kesepakatan dengan mitra dan tersedianya bahan dan tempat, maka diputuskan bahwa kiln pirolisis dibuat dengan ukuran panjang 4,5 m dan lebar 3,5 m. Sebagian kiln digali untuk menambah kapasitas.

3.3. Pengujian Arang

Arang (biochar) digiling dan digunakan sebagai bahan pembenah tanah (soil amendment) pada budidaya tanaman sawi pakcoy dan tanaman jagung. Penelitian dilakukan pada skala lab menggunakan pot. Penelitian dilakukan di Lab Lapang Terpadu, Fakultas Pertanian. Penelitian bertujuan untuk mengetahu efek pemberian biochar dan pupuk kimia (Urea).

Rancangan percobaan yang digunakan dalam penelitian ini adalah Rancangan Acak Lengkap (RAL) faktorial dengan dua faktor dan tiga kali ulangan. Faktor percobaan pada penelitian ini terdiri dari: faktor suhu pirolisis *biochar* (250^{o}C, 300^{o}C dan 350^{o}C) dan faktor dosis urea (0,6g, 1,2g dan 1,8g) per tanaman (pot).

Parameter yang diamati pada penelitian ini adalah sebagai berikut:

a) karakteristik tanah dan *biochar*,

- Kadar air, diukur dengan cara pengovenan menggunakan oven memmer pada suhu 105 ^{o}C selama 24 jam

  Kadar air sampel dapat dihitung dengan:

Kadar Air (%) $= \frac{BB-BK}{BK}$ x 100% ……………………………. (1)

- Kadar abu (*biochar*), diukur dengan cara ditanur menggunakan tanur (Muffle Furnace FB 1410-M33) pada suhu 550 ^{o}C selama 4 jam

  Kadar Abu (%) $= \frac{\text{Berat abu (gr)}}{\text{Berat sampel(gr)}}$ x 100% ……………………(2)

- Berat isi (*bulk density),* pengukuran pada sampel tanah, sampel *biochar* dan media tanam setelah panen dengan menggunakan ring sampel dengan diameter 5,5 cm sebagai faktor/pembagi.

  BD sampel (g/cm^3) $= \frac{\text{Berat tanah}}{\text{Volume ring}}$ ……………………………. (3)

- Susut tanah (cm), pengukuran dilakukan dengan mengukur tinggi permukaan tanah awal dan akhir lalu dihitung susut tanah (tinggi akhir – tinggi awal)
- pH (tanah dan *biochar),* pengukuran pada sampel tanah, sampel *biochar* dan media tanam setelah panen dengan menggunakan indikator pH meter

b) Kebutuhan air, dilakukan setiap hari pada sore hari diikuti dengan pemberian air irigasi untuk mengembalikan kondisi awal (air tersedia)

c) Produktivitas air dan produktivitas pupuk.

Produktivitas (%) $= \frac{\text{jumlah total (air atau pupuk)}}{\text{bobot total segar pakcoy}}$ x 100% …………...(4)

d) Tinggi tanaman, jumlah daun, lebar daun, warna daun, luas kanopi, dilakukan pengamatan setiap 4 hari sekali

- Warna daun, pengukuran menggunakan colorimeter (Amtast AMT507) yang menghasilkan nilai kehijauan (-*a*) yang nantinya diintrepretasikan dengan membandingkan nilai *a* untuk melihat perbedaan warna daun
- Luas kanopi diukur menggunakan aplikasi Canopy Cover yang tersedia pada android. Pot dilengkapi frame persegi ukuran 3.552,16 cm^2 yang dipasang setinggi permukaan tanah dalam pot. Tanaman difoto dari ketinggian tertentu dimana seluruh frame tepat mengenai tepi layar smart phone. Setelah itu aplikasi otomatis memindai (*scanning),* luas kanopi sesuai warna daun akan ditampilkan dalam % frame dan luas canopy diperoleh dari mengalikan % luas kanopi dengan luas frame (Gambar 5).

Gambar 5. Pengukuran luas kanopi tanaman pakcoy menggunakan aplikasi Canopy Cover

3.4. Analisis Data

Data yang diperoleh dianalisis dengan menggunakan analisis sidik ragam. Analisis dilakukan dengan menggunakan perangkat lunak SAS versi 9.13. Jika dalam hasil analisis sidik ragam terdapat pengaruh nyata dari faktor percobaan pada taraf (P>5%), maka analisa dilanjutkan dengan uji BNT (Beda Nyata Terkecil) untuk melihat pengaruh interaksi antar perlakuan pada taraf (P>5%). Hasil analisa atau pengolahan data akan disajikan dalam bentuk grafik, tabel dan notasi serta diuraikan secara deskriptif.

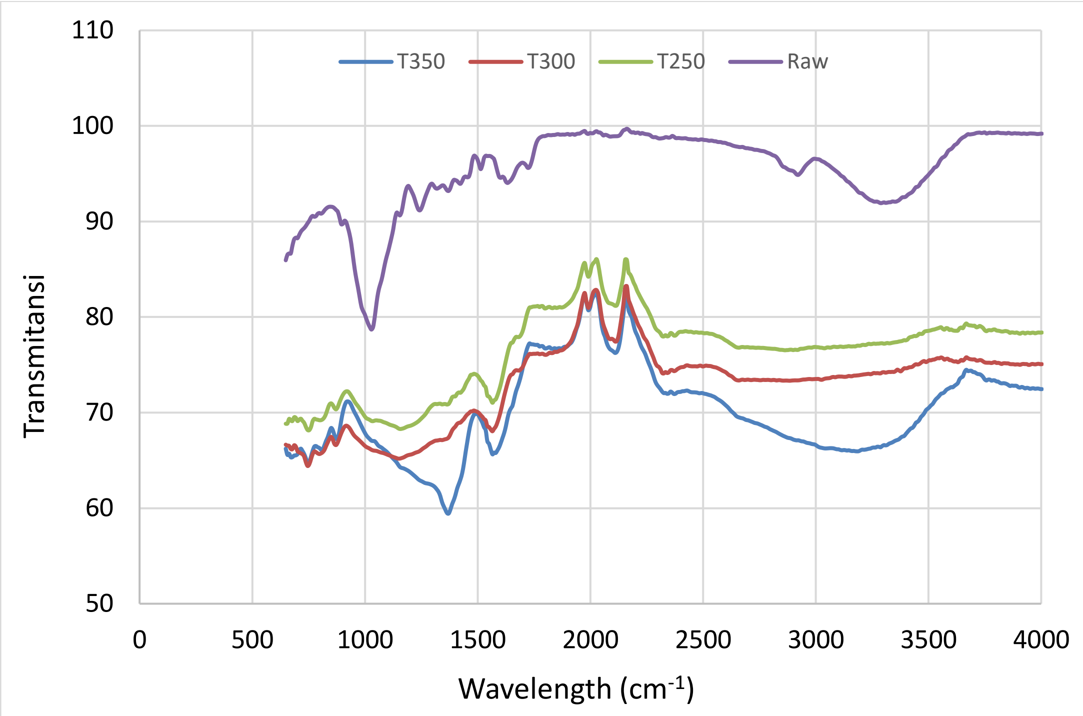
BAB 4. HASIL DAN PEMBAHASAN

4.1. Kiln Pirolisis

Kiln pirolisis dibuat dengan ukuran 3,5 m x 4,5 m. Dengan kedalaman sampai 1,5 m, maka kiln memiliki kapasitas hingga 23,6 m^3. Hasil pengukuran menunjukkan bahwa janggel jagung memiliki densitas curah rata-rata 0,33 ton/m^3. Oleh karena itu kiln ini bisa memproses janggel jagung tidak kurang dari 7 ton sekali jalan. Kiln memiliki 2 pipa untuk penyalaan pembakaran. Kiln dilengkapi dengan kerangka dari besi dan atap dari pelat besi yang dapat dilipat. Selain itu, kiln dilindungi dengan atap dari asbes. Dalam pengujian diperlukan waktu 2 hari dalam sekali proses. Tetapi hasilnya belum optimal karena belum semua tongkol jagung sudah terpirolisis. Oleh karena itu waktu proses harus diperpanjang hingga paling sedikit 3 hari.

Gambar 4. Kiln (tungku) pirolisis tongkol jagung

Secara terpisah, pirolisis tongkol jagung dilakukan pada suhu 250, 300, dan 350 ^oC. Hal ini dilakukan untuk mengetahui efek suhu terhadap karakteristik biochar. Gambar 5 menunjukkan profil uji FTIR untuk biochar tongkol jagung.



Gambar 5. Hasil uji FTIR biochar tongkol jagung

Tabel 3. Karakteristik biochar tongkol jagung hasil pirolisis pada suhu 250-350^{o}C

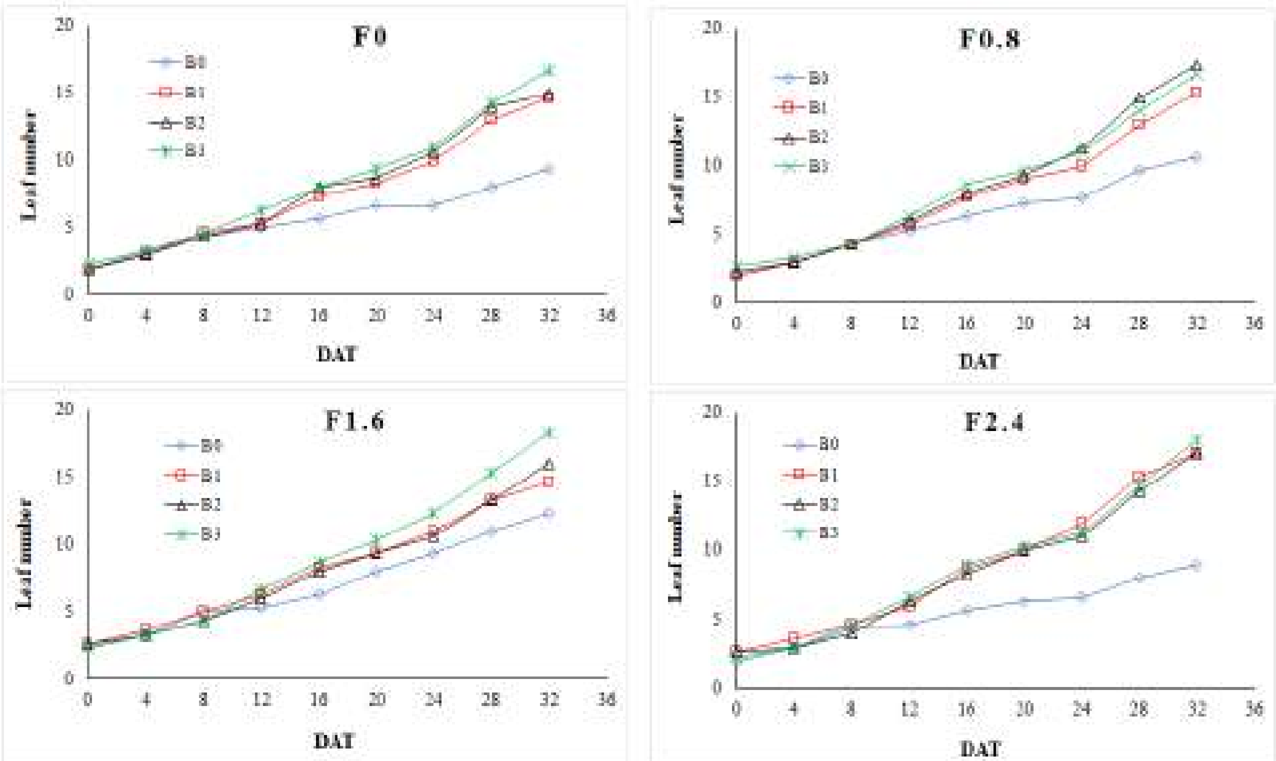
Variabel	***Biochar***		
	250 ^{o}C	**300 ^{o}C**	**350 ^{o}C**
pH	9	9 -10	10
Bulk density (gr/cm3)	0,228	0,328	0,209
Kadar air basis kering (%)	3,65	3,65	3,65
Kadar abu (%)	8,32	10,49	9,21

Tabel 3 memperlihatkan Karakteristik biochar tongkol jagung hasil pirolisis pada suhu 250-350 ^{o}C. Pada hasil uji laboratorium yang dilakukan didapatkan pH *biochar* suhu 250, 300 dan 350 ^{o}C masing-masing sebesar 9, 9-10 dan 10. Ini menunjukkan bahwa semakin besar suhu yang digunakan saat proses pembuatan *biochar* maka semakin besar pula pH pada *biochar* tersebut sehingga penambahan *biochar* pada tanah ultisol (pH rendah) dapat meningkatkan nilai pH menuju kondisi netral. Berat isi (bulk density) *biochar* pada masing-masing suhu didapat nilai bulk density yang berbeda, berdasarkan hasil analisis yang telah dilakukan dapat disimpulkan bahwa *biochar* pada suhu 250 ^{o}C memiliki nilai bulk density tertinggi diantara *biochar* yang lain. Bulk density memiliki nilai yang berbanding terbalik dengan kandungan bahan organik suatu bahan, semakin tinggi bulk density suatu bahan makan semakin sedikit kandungan bahan organik bahan tersebut.

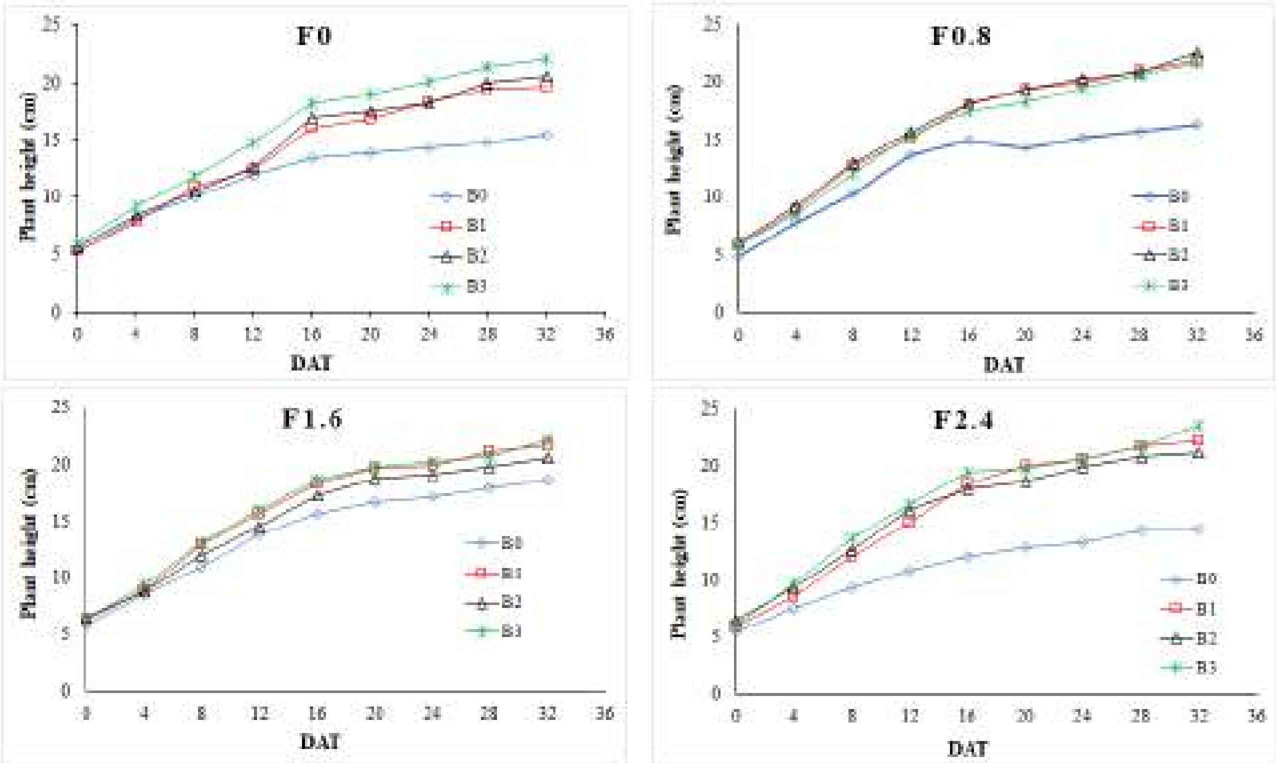
4.2. Pengujian Biochar

Arang (biochar) hasil pirolisis tongkol jagung digiling dan dimanfaatkan sebagai bahan pembenah tanah (*soil amendment*) pada budidaya tanaman sawi pakcoy dan jagung. Pada pengujian dengan tanaman sawi pakcoy, dosis biochar tongkol jagung adalah 90 g per pot atau 3% dari berat total media tanam. Parameter penting yang diamati mliputi tinggi tanaman, jumlah daun, luas kanopi, berat brangkasan segar, produktivitas pupuk, dan produktivitas air.

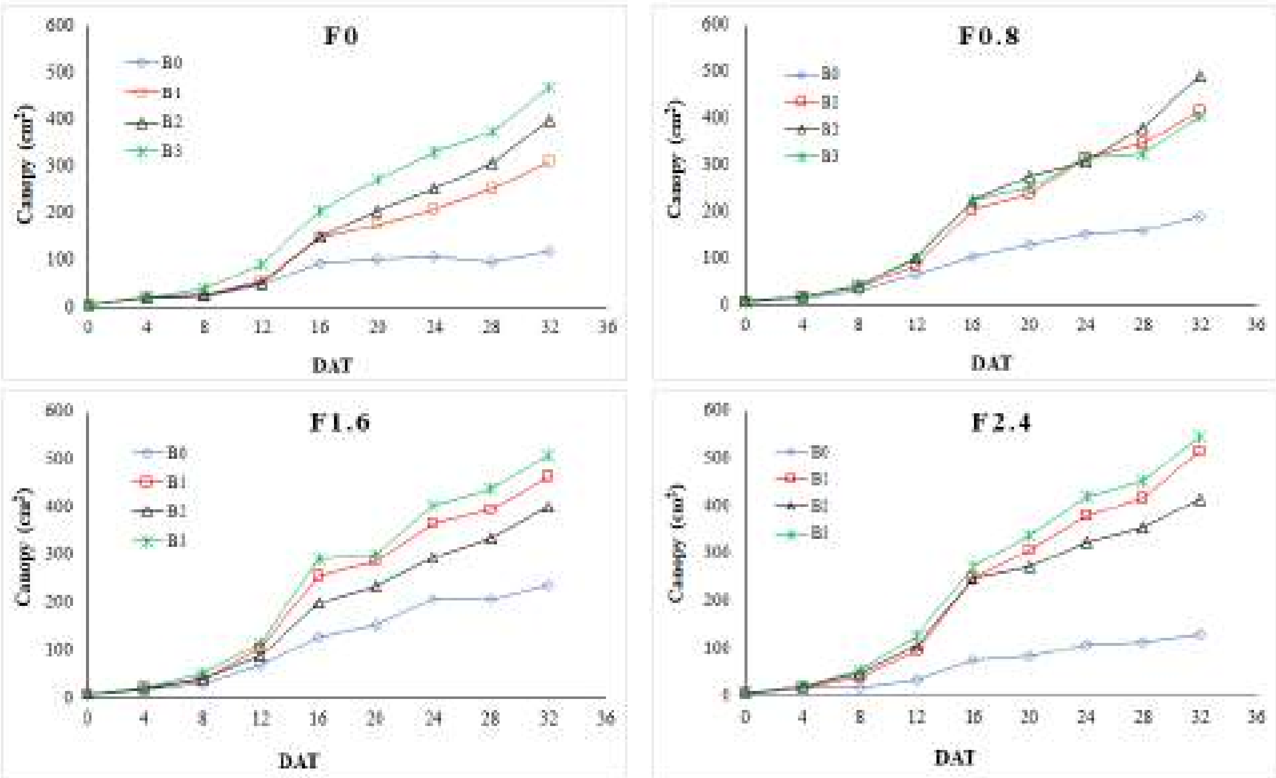
Gambar 6–8 menunjukkan perkembangan jumlah daun, tinggi tanaman, dan luas kanopi sampai hari ke 32 (sebelum panen). Selain itu, Tabel 4 menunjukkan pengaruh perlakuan terhadap parameter tanaman, yaitu jumlah daun, tinggi tanaman, luas kanopi, hasil panen segar, dan produktivitas air Pak choi pada 32 HST. Tabel 3 juga disajikan untuk mengetahui efektivitas perlakuan terhadap produktivitas pupuk.



Gambar 6. Perkembangan jumlah daun tanaman sawi Pakcoy



Gambar 7. Perkembangan tinggi tanaman sawi Pakcoy



Gambar 8. Perkembangan luas kanopi tanaman sawi Pakcoy

Tabel 4. Pengaruh perlakuan terhadap jumlah daun, tinggi tanaman, luas kanopi, dan hasil tanaman pada hari ke-32 setelah pindah tanam.

Hasil tanaman segar (g/pot)					
Biochar	F0	F0.6	F1.2	F1.8	Average
B0	7.4	9.8	13.7	6.2	9.3 c
B250	16.3	23.4	28.3	33.2	25.3 ab
B300	21.3	29.4	23.4	25.9	25.0 b
B350	26.4	26.8	33.5	35.7	30.6 a
Rata-rata	17.8 B	22.3 AB	24.7 A	25.2 A	
Tinggi tanaman (cm)					
B0	15.7	16.3	18.6	14.4	16.3 b
B250	20.3	21.9	21.7	22.1	21.5 a
B300	20.9	22.5	20.6	21.2	21.3 a
B350	22.0	21.6	22.1	23.5	22.3 a
Average	19.7	20.6	20.8	20.3	
Jumlah daun					
B0	10	11	13	9	11 c
B250	15	16	15	17	16 bc
B300	15	18	16	17	17 ab
B350	17	17	19	18	18 a
Average	14	15	16	16	
Luas kanopi (cm^2)					
B0	119.6	190.6	236.8	130.2	169.3 c
B250	309.0	415.6	461.8	511.5	424.5 ab
B300	397.8	478.4	400.2	406.1	420.6 b
B350	466.5	403.8	510.3	522.2	475.7 a
Average	323.2 B	372.1 AB	402.3 A	392.5 A	
Produktivitas Air (g/L)					
Biochar	F0	F0.6	F1.2	F1.8	Average
B0	2.77	5.62	6.98	10.23	6.40 b
B250	4.37	9.49	12.74	10.90	9.37 a
B300	6.06	10.95	8.85	13.28	9.78 a
B350	2.69	13.56	8.94	15.16	10.09 a
Average	3.97 C	9.90 B	9.37 B	12.39 A	

Keterangan: Angka yang diikuti huruf yang sama tidak berbeda pada α = 5%: huruf kecil untuk kolom (perlakuan biochar), huruf capital untuk baris (dosis Urea).

Tabel 5. Pengaruh perlakuan terhadap produktivitas pupuk (g/g).

Biochar	F0.6	F1.2	F1.8
B0	21.60 cde	15.48 ef	4.62 fg
B250	53.32 b	31.43 cd	25.42 cde
B300	73.79 a	24.78 cde	18.63 def
B350	53.39 b	35.87 c	27.59 cde

Keterangan: Angka yang diikuti huruf yang sama tidak berbeda pada α = 5%.

4.2.1. Perkembangan dan Hasil Tanaman

Gambar 6 sampai 8 menunjukkan pertumbuhan tanaman pak choi selama 32 hari yang ditunjukkan oleh parameter tanaman seperti jumlah daun, tinggi tanaman, dan luas tajuk. Dari gambar tersebut terlihat bahwa pertumbuhan pak choi pada media tanam tanpa penambahan biochar selalu lebih rendah dibandingkan dengan tanaman yang ditanam pada media yang diberi biochar pada semua dosis pupuk Urea. Hal ini menunjukkan keunggulan biochar sebagai pembenah tanah. Produksi pak choi dalam penelitian ini rata-rata berada pada kisaran 9,3 hingga 30,6 g/tanaman (Tabel 4). Dengan asumsi jarak tanam 20x25 cm (Wiangsamut & Koolpluksee, 2020), hasil maksimum adalah 6,12 t/ha. Angka ini sangat mendekati rata-rata produktivitas pak choi di Lampung yaitu 6,84 t/ha (BPS Provinsi Lampung, 2020). Namun demikian, masih jauh lebih rendah dibandingkan penelitian (Wiangsamut & Koolpluksee, 2020) dengan hasil 18,76 t/ha. Kombinasi faktor tanah ultisol masam dan tidak subur ditambah dengan suhu tinggi dan RH rendah di rumah kaca dapat menyebabkan rendahnya produksi tanaman Pak choi.

Tabel 4 menunjukkan bahwa faktor interaksi suhu pirolisis biochar tongkol jagung dan dosis pupuk Urea tidak berpengaruh nyata terhadap hasil panen pada taraf = 0,05. Namun kedua faktor tersebut secara terpisah berpengaruh nyata terhadap luas tajuk dan hasil tanaman pak coi (α = 0,05). Semakin tinggi dosis pupuk meningkat produksi tanaman. Pada dosis rendah (0,6 g/pot) pengaruh pupuk urea tidak nyata. Namun, pada dosis yang lebih tinggi (1,2 dan 1,8 g/pot) pengaruh pupuk Urea sangat nyata jika dibandingkan dengan tanaman tanpa aplikasi pupuk. Telah diketahui bahwa pupuk nitrogen penting untuk mencapai hasil tinggi dan kualitas sayuran yang baik (Tei et al., 1999).

Aplikasi biochar secara signifikan meningkatkan produksi tanaman Pak choi rata-rata 290% dari 9,3 g/tanaman (tanpa biochar) menjadi 25,3 – 30,6 g/tan (dengan penambahan biochar tongkol jagung). Dari tabel tersebut dapat dilihat bahwa semakin tinggi suhu pirolisis tongkol jagung memberikan pengaruh positif yang signifikan terhadap hasil panen. Hasil tertinggi (30,6 g) diperoleh dari media tanam yang diubah dengan biochar yang dibuat pada 350 C. Temperatur pirolisis yang lebih tinggi menghasilkan biochar dengan struktur yang lebih berpori, luas permukaan spesifik yang lebih tinggi, dan volume pori yang lebih tinggi (Singh et al., 2010). Sifat-sifat ini bermanfaat bagi biochar sebagai pembenah tanah.

4.2.2. Jumlah Daun dan Tinggi Tanaman

Tabel 4 juga menunjukkan temuan menarik dimana dosis pupuk Urea tidak berpengaruh nyata terhadap jumlah daun dan tinggi tanaman Pak choi. Jumlah daun pak choi tanpa pupuk rata-rata 14 daun, tidak berbeda secara statistik dengan pemberian pupuk (15-16). Demikian pula tinggi tanaman tanpa pupuk adalah 19,7 cm, tidak berbeda nyata dengan yang ditanam dengan Urea (20,3-20,8 cm). Hal ini dapat disebabkan oleh dosis pemupukan yang terlalu rendah, mengingat tanah bersifat masam dan tidak subur.

Di sisi lain, biochar mampu meningkatkan jumlah daun dan tinggi tanaman secara signifikan. Tinggi tanaman tanpa biochar (16,3 cm) nyata lebih rendah dibandingkan tinggi tanaman dengan biochar (21,3-21,5 cm). Aplikasi biochar, terlepas dari suhu pirolisis, meningkatkan tinggi tanaman antara 30,7 hingga 36,8% dibandingkan dengan kontrol tanpa biochar. Tabel 4 juga menunjukkan bahwa semakin tinggi suhu pirolisis berpengaruh positif terhadap jumlah daun tetapi tidak terhadap tinggi tanaman Pak choi. Pak choi ditransplantasikan ketika tanaman memiliki tiga daun sejati. Selama pertumbuhan, jumlah daun meningkat rata-rata 8 (tanpa biochar) dan 13-15 dengan biochar atau penampakan daun 0,40-0,47 d^{-1}. Hal ini memberikan penjelasan bahwa suhu pirolisis biochar berkorelasi positif dengan hasil tanaman, salah satunya melalui peningkatan jumlah daun. Penambahan biochar pada tanah yang kekurangan unsur hara meningkatkan pertumbuhan tanaman dan penyerapan unsur hara lebih optimal. Hasil kami lebih baik dari yang dilaporkan (Gunawan & Susylowati, 2013) dengan pertambahan antara 8 sampai 10 daun.

4.2.3. Luas Kanopi

Pengaruh perlakuan terhadap luas tajuk sama dengan pengaruhnya terhadap hasil panen dimana pemupukan 0,6 g/pot tidak nyata secara statistik. Pada dosis Urea 1,2 dan 1,8 luas tajuk tanaman meningkat signifikan dibandingkan dengan luas tajuk tanaman tanpa pupuk. Hubungan antara dosis N dan indeks luas daun jagung dan bunga matahari dilaporkan di mana luas daun menurun di bawah konsentrasi N terbatas karena berkurangnya fotosintesis oleh daun, laju perkembangan luas daun yang lebih rendah dan peningkatan penuaan daun (Massignam et al., 2011).

Luas tajuk dipengaruhi oleh jumlah daun, lebar daun, dan struktur daun. Sebelumnya ditunjukkan bahwa jumlah daun dan tinggi tanaman tidak dipengaruhi oleh dosis pupuk. Dengan demikian, peningkatan luas tajuk dengan dosis pemupukan berimplikasi pada peningkatan lebar daun. Hasil pengukuran membuktikan bahwa penambahan pupuk menghasilkan peningkatan lebar daun yang signifikan dengan nilai rata-rata 6,71 cm tanpa pupuk dan 7,56, 7,33, dan 7,34 cm untuk tanaman dengan dosis pupuk masing-masing 0,6, 1,2, dan 1,8 g/pot. Pengaruh dosis pemupukan 0,6 – 1,8 g/tanaman terhadap lebar daun tidak berbeda secara statistik pada $\alpha = 0,05$. Demikian pula, penambahan biochar secara signifikan meningkatkan lebar daun dari 5,23 cm (tanpa biochar) masing-masing menjadi 7,83, 7,73, dan 8,17 cm untuk penambahan biochar dengan suhu pirolisis 250, 300, dan 350 C. Namun pengaruh suhu pirolisis terhadap lebar daun juga tidak nyata pada = 0,05. Dilaporkan bahwa indeks luas daun jagung yang dibudidayakan di tanah yang diubah dengan biochar secara signifikan lebih besar daripada perlakuan kontrol (tanpa penambahan biochar) (Njoku et al., 2015).

4.2.4. Produktivitas Air dan Pupuk

Produktivitas air adalah rasio hasil panen dengan total air yang disuplai ke tanaman. Tabel 4 menunjukkan bahwa dosis Urea secara signifikan meningkatkan produktivitas air sebesar 312% dari rata-rata 3,97 g/L (tanpa pupuk) menjadi 12,39 g/L (dosis urea 1,8 g/pot). Penambahan biochar juga meningkatkan produktivitas air Pak choi tetapi pada tingkat yang lebih rendah dengan rata-rata 152% dari 6,40 g/L (tanpa biochar) menjadi 9,37-10,09 g/L (dengan biochar). Selain itu, Tabel 4 menunjukkan bahwa pengaruh suhu pirolisis terhadap produktivitas air tidak signifikan pada taraf = 0,05.

Kami juga menghitung pengaruh perlakuan terhadap produktivitas pupuk Pak choi, dan hasilnya disajikan pada Tabel 5. Interaksi dosis Urea dan suhu pirolisis berpengaruh nyata terhadap produktivitas pupuk. Terdapat pola yang konsisten dimana peningkatan dosis pupuk mengakibatkan penurunan produktivitas pupuk pada setiap perlakuan biochar. Hal ini berarti peningkatan hasil pak choi lebih rendah dibandingkan dengan laju peningkatan dosis pupuk urea.

4.3. Pengujian Lain

Secara terpisah, biochar tongkol jagung sedang diuji oleh tim lain untuk aplikasi sebagai pembenah tanah pada budidaya tanaman jagung. Pada saat laporan ini dibuat jagung baru berumur 1 bulan.

4.4. Luaran

Luaran dalam bentuk makalah untuk jurnal internasional bereputasi (Q3) telah disubmit pada 10 September 2021 ke Journal of Agriculture and Rural Development in the Tropics and Subtropics. Hingga saat ini statusnya adalah *Awaiting Assignment* (LAMPIRAN).

BAB 5. KESIMPULAN

Dalam penelitian ini telah berhasil dibuat kiln untuk pirolisis tongkol jagung berukuran panjang 4,5 m, panjang 3,5 m, dan kedalaman 1,5 m. Kiln mampu memproses 7 ton tongko, jagung untuk diproses menjadi biochar. Selanjutnya biochar digiling untuk digunakan sebagai bahan pembenah tanah.

Pengujian biochar tongkol jagung sebagai pembenah tanah dalam budidaya pak choi telah dilakukan dan menunjukkan efek jangka pendek biochar terhadap pertumbuhan dan hasil tanaman. Tanpa penambahan biochar, media tanam menghasilkan pertumbuhan dan hasil yang jauh lebih rendah dibandingkan media dengan biochar pada semua dosis pupuk Urea. Media tanam yang diberi biochar menunjukkan pertumbuhan tanaman yang lebih baik secara statistik dibandingkan tanpa biochar untuk semua parameter pertumbuhan (jumlah daun, tinggi tanaman, luas tajuk, dan hasil panen). Hasil tanaman dengan penambahan biochar meningkat 290% dibandingkan tanpa biochar. Suhu pirolisis tongkol jagung berpengaruh nyata (□ = 0,05) terhadap parameter tinggi tanaman, jumlah daun, luas tajuk, dan hasil panen. Suhu pirolisis biochar 350 C memberikan pengaruh terbaik dengan hasil rata-rata bobot brangkasan segar 30,6 g/tanaman, tinggi tanaman 22,3 cm, lebar daun 8,2 cm, jumlah daun 17,4, produktivitas air 10,09 g/L, dan produktivitas pemupukan. 27,59-53,39 g/g tergantung dosis pemupukan.

BAB 6. BIAYA DAN JADWAL PENELITIAN

6.1. Anggaran Biaya

Biaya yang diperlukan untuk kegiatan ini adalah Rp50.000.000,- (lima puluh juta rupiah) dengan perkiraan komposisi biaya diberikan dalam Tabel 6. Secara rinci Rencana Anggaran dan Biaya digunakan untuk keperluan sebagaimana diberikan dalam Tabel 7.

Tabel 6. Anggaran biaya penelitian enkapsulasi benih dengan pupuk organonitrofos

No	Komponen	Jumlah (Rp)	Persentase
1.	Pengadaan alat dan bahan penelitian	32.275.000	64,55
2.	Biaya perjalanan penelitian	5.000.000	10,00
3.	Alat tulis kantor/bahan habis pakai	3.910.875	7,82
4.	Laporan/Diseminasi/Publikasi	8.814.125	17,63
	TOTAL	50.000.000	100,00

Tabel 7. Rincian anggaran biaya penelitian pengembangan teknologi pirolisis biomassa limbah jagung tahun 2021.

No	Item	Kuantitas	Harga unit (Rp)	Jumlah (Rp)
1	Pembuatan tungku pirolisis + 2 uji coba	1 unit	22.000.000	20.000.000
2	Belanja bahan kimia	1 paket	6.140.000	6.140.000
3	Belanja bahan gelas	1 paket	3.355.000	3.355.000
4	Belanja bahan kimia	1 paket	2.780.000	2.780.000
5	Transportasi lokal	5 kali	700.000	3.500.000
6	Biaya lumpsum	10 OH	150.000	1.500.000
7	Analisis arang (Uji FTIR)	4 sampel	35.000	140.000
8	Analisis arang (Uji N, P, K, C)	3 sampel	410.000	1.230.000
9	ATK (kertas, tinta, materai, alat tulis)	1 kali	500.000	540.875
10	Enumerator	1 bln	2.000.000	2.000.000
11	Biaya publikasi Internasional bereputasi	1 kali	5.000.000	5.000.000
12	Pajak	1 kali	1.814.125	1.814.125
13	Biaya Seminar Internasional	1 kali	2.500.000	2.000.000
	JUMLAH			50.000.000

6.2. Jadwal Penelitian

Penelitian ini akan dilaksanakan dalam waktu 6 bulan. Tahap-tahap kegiatan dan jadwal penelitian secara spesifik diberikan dalam Tabel 8.

Tabel 8. Kegiatan penelitian menurut tahapan dan perkiraan waktu pelaksanaannya

Kegiatan	Bln1		Bln2		Bln3		Bln4		Bln5		Bln6	
Persiapan (koordinasi tim)												
Belanja alat dan bahan habis												
Pembuatan tungku pirolisis												
Pengujian tungku pirolisis												
Analisis sifat arang												
Pelaksanaan Seminar												
Publikasi jurnal internasional bereputasi												
Penyusunan laporan keuangan												
Pembuatan laporan akhir												

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LAMPIRAN: DRAFT MAKALAH ILMIAH

STATUS: Awaiting Assignment

JURNAL: Journal of Agriculture and Rural Development in the Tropics and Subtropics

Application of Corncob Biochar and Urea for Pak choi (*Brassica rapa* L.) Cultivation: Short-Term Impact of Pyrolysis Temperature and Fertiliser Dose on Plant Growth and Yield

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Abstract

This study aimed to evaluate the effect of pyrolysis temperature of corncob biochar as soil amendment and urea fertiliser on the growth and yield of Pak choi. The dose of biochar was 90 g with total growing media of 3000 g. Two factors, namely pyrolysis temperature of biochar and fertiliser dose consisting of 4 levels each were randomly design with three replications. Pak choi cultivation was performed in pots (13 cm height, 19 cm upper diameter, and 13.5 cm bottom diameter). The results showed pyrolysis temperature was significant (α = 0.05) on growth parameters, fresh yield, water productivity and fertiliser productivity. Pyrolysis temperature of 350 °C resulted in the highest growth and production at an average yield of 30.6 g/plant, water productivity of 10.09 g/cm^3, and fertiliser productivity of 27.59-53.39 g/g depending on the dose.

Keywords: Biochar, Water productivity, Fertiliser productivity, Canopy, Leaf number

Introduction

Developed in China, Pak choi (*Brassica rapa* L) is a leafy, green vegetable now consumed nearly all over the world and an economically valuable commodity in many countries. In Indonesia, Pak choi is one of the favorite vegetables for various dishes and increasingly popular because of its short cultivation period with a harvesting time of 25-35 days after transplanting. Pak choi planted area gradually increased (1.8% during four years) from 61,133 ha in 2017 to 62.228 ha in 2020 (BPS, 2021). In the same period, Pak choi production increased 6.1% from 627,611 t/y (2017) to 665.668 t/y (2020) with average productivity of 10.7 t/ha. Pak choi productivity in Lampung (6.84 t/ha) is significantly lower than the national level. Inefficient cultivation techniques and infertile soil are important factors causing the low productivity in Lampung. Lampung Province has a wide expanse of dry upland acid soils of the ultisol type which generally are suboptimal land characterized by low cation exchange capacity (CEC), low organic matter, low water holding capacity, and high aluminium (Al) and high P fixation (Cornelissen et al., 2018). Therefore, efforts to increase soil fertility by appliying of soil amendment materials such as compost and biochar are of great importance.

The application of biochar as a soil amendment has been sharply increases during the last decade. Biochar is a porous, carbon-rich organic material produced through pyrolysis. Under very limited or no oxygen, pyrolysis converts biomass to a stable carbon (C) form that will stand for such a long time that it plays a vital role in C sequestration (Crombie et al., 2013). In soil, biochar acts as a sponge-like material with a high surface area that enhances water holding capacity thereby capable of reducing soil erosion (Hseu et al., 2014). Biochar increase nutrient and fertiliser retention and improves fertiliser efficiency (Liu et al., 2019). In addition, the ash content in biochar provides a liming effect that alleviate soil acidity (Cornelissen et al., 2018). Biochar also facilitates a good home for soil microorganisms that improve soil fertility (Lehmann et al., 2011). Interaction of these properties climaxes in the increased of soil productivity and plant yield. For example, even though no significant effect on grain yield, biochar application on rice increased soil pH, nitrate, mineral content (K, Ca, Mg, Mn), and CEC, while reducing Al (Carvalho et al., 2013). A combination of corncob biochar and low rate fertiliser (25% of recommended dose) in the humid season in Tanzania increased dry biomass yield by 83% and was comparable to that of full dose (Kiobia et al., 2019).

The application of biochar to increase the yield of Pak choi has been reported (Silitonga et al., 2018; Sugiyarto et al., 2021). Although crop yield did not significantly different due to biochar application, corncob biochar was reported to produce the highest number of Pak choi leaves compared to biochar from rice husk, coconut shell, oil palm waste, or coffee husk (Sugiyarto et al., 2021). Biochar application in acidic soil significantly increases Pak choi yield for five seasons regardless of nitrogen application (Yu et al., 2015). Application of rice husk biochar at medium (5% w/w) and high (10% w/w) dose increases aerial biomass yield of *Brassica rapa* L. in contaminated soils (Campos et al., 2021).

The effects of biochar application depend on feedstock type and pyrolysis conditions such as reaction time, temperature, and heating speed, (Tomczyk et al., 2020). Feedstock type dictates mineral composition, total organic carbon, and fixed carbon of biochar, while pyrolysis temperature determines pH and surface area of biochar (Zhao et al., 2013). Whereas, pyrolysis conditions determine biochar characteristics. Biochars produced using a top-lit updraft stove at high temperature are better for soil amendment due to their adsorption capacities and chemical stability as compared to those of low-temperature anaerobic charring using a retort (Kaal et al., 2017). This study, therefore, aims to provide information about the effect of the pyrolysis temperature of corncob biochar and its application on the yield of Pak choi, the effectiveness of using urea fertiliser, and water productivity.

Materials and Methods

Research was conducted in a greenhouse of the University of Lampung, Indonesia (5°22’7” S, 105°14’33” E) from November 2020 to February 2021. Corncob was chosen as feedstock for biochar because of its abundant availability in Lampung as Indonesia’s top three corn producing regions. The dry corncob was pyrolysed at three different temperatures (250, 300 and 350 ℃) using a covered drum externally heated using an LPG stove. Pyrolysis temperature was maintained by controlling flame intensity through the gas flowrate adjustment knob. The resulted biochar was ground and sieved using a 20 mesh (0,9 mm) screen. Ultisol soil collected from the subsoil layer within the university field laboratory had a composition of 29% sand, 30% silt, and 42% clay. It was sieved using a 3-mm soil screen and was then mixed thoroughly with biochar at a ratio of 90 g biochar with 2910 g soil to make a total of 3000 g growing media. Some properties of the soil and corncob biochar used in the experiment are presented in Table 1.

The growing media was filled into pots (13 cm height, 19 cm upper diameter, and 13.5 cm bottom diameter) and watered with pre-measured water to have a field capacity condition. Pak choi seed purchased from local farm shop was seedled for two weeks. Seedlings with a good vigor were transplanted into the prepared media. The pots were watered daily to replace the evapotranspiration loss as measured by the weighing method. Fertilisation was applied at 14 day after transplanting (DAT) and 21 DAT with half a dose for each application. The plants were harvested at 32 DAT.

Table 1. Properties of soil and biochar used in the experiment

Property	Value	Criteria	
Soil			
N-total (%)	0.04	Very low	
P-available (ppm)	11.85	Low	
C-organic (%)	0.38	Very low	
K-dd (mg/100gr)	0.09	Very low	
pH (initial)	4.5-5.5	Acid/medium	
pH (after harvesting)	6.0-8.0	Neutral	
Biochar	**250 ℃**	**300 ℃**	**350 ℃**
pH	9	10	10
Density (g/cm^3)	0.228	0.328	0.209

Experimental Design

The pot trial was conducted in a factorial design with two factors, namely pyrolysis temperature (no biochar, 250, 300 and 350 ℃) and urea dose (0, 0.6, 1.2, and 1.8 g/pot). All treatment combinations with three replications were completely randomised.

Analysis and Measurements

Parameters including water consumption, plant growth, canopy cover, and crop yield (fresh and dry basis) were monitored during plant growth. After harvesting, soil pH was observed. In addition, water productivity and fertiliser productivity were also calculated. The canopy cover was measured using the Canopy Cover Free application available on android. In this case, a styrofoam square of 60 cm side was used as a guide frame. The image was taken from such height that the guide frame is included precisely in the smartphone screen. After filtering, the canopy was presented as a percentage of the guide frame area. Water productivity (WP) and fertiliser productivity (FP) were calculated as fresh yield over water consumption and urea dose, respectively.

Statistical Analysis

Analysis of variance (ANOVA) and the least significant difference (LSD) test were performed using the SAS program ver. 9.13 to see the effect of treatment on the dependent variables at α = 5%.

RESULTS

Figures 1 to 3 show the development of leaf number, plant height, and canopy area up to day 32 (just before harvesting). In addition, Table 2 shows the treatment effect on plant parameters, namely number of leaves, plant height, canopy cover, fresh crop yield, and water productivity of Pak choi at 32 DAT. Table 3 is also presented to determine the effectiveness of the treatment on the fertiliser productivity.

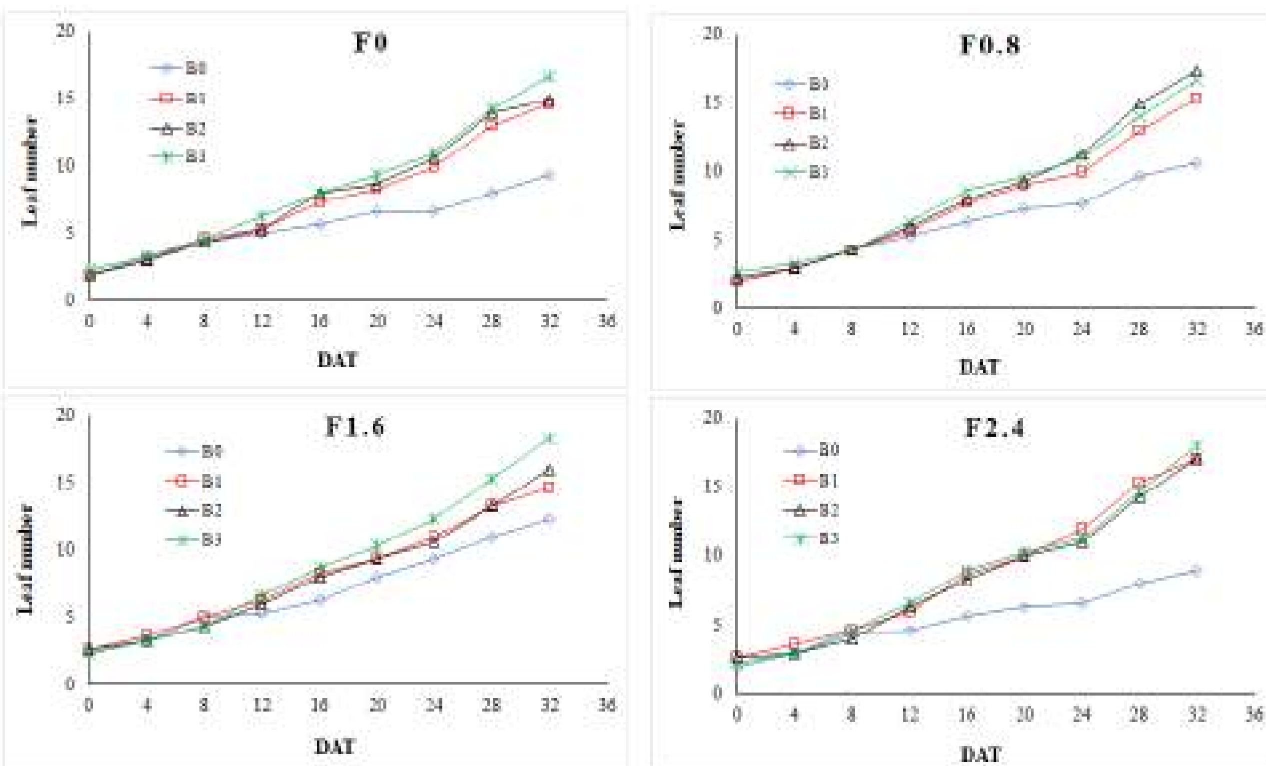

Figure 1. Development of leaf number of Pak choi for different treatments.

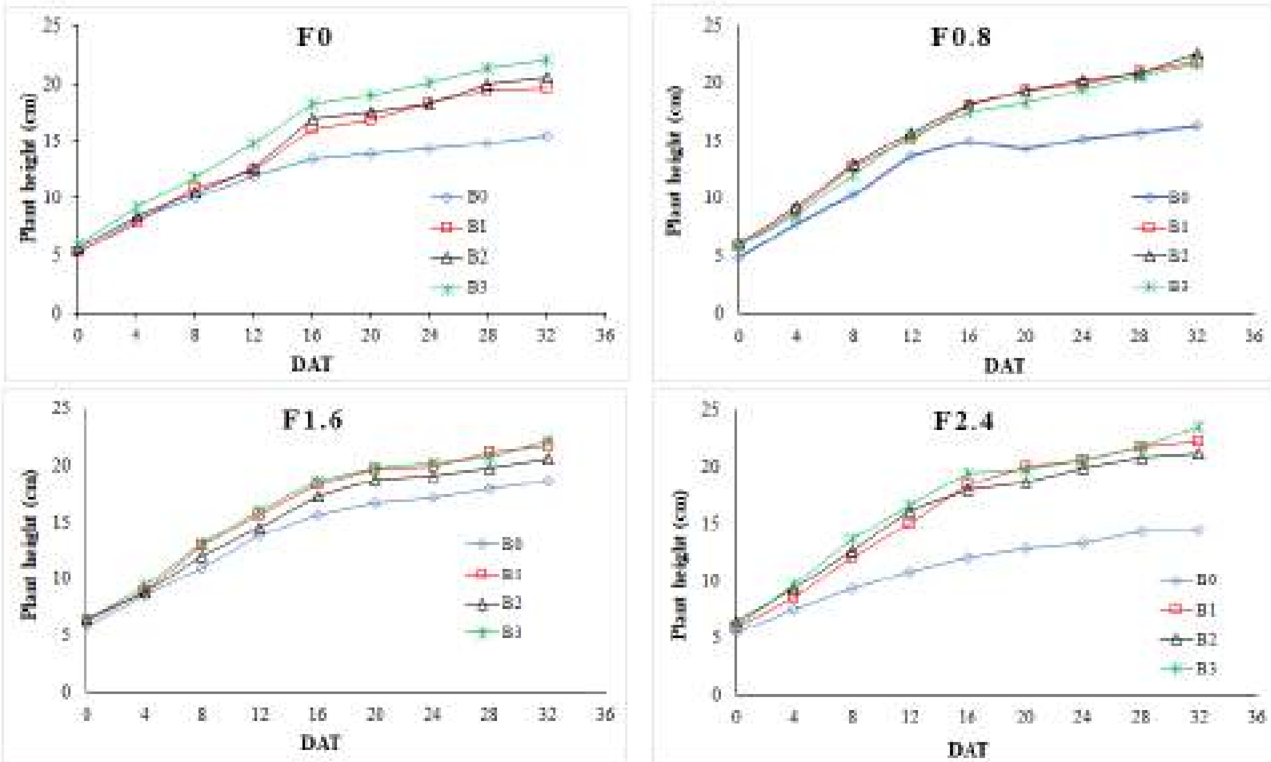

Figure 2. Development of plant height of Pak choi for different treatments.

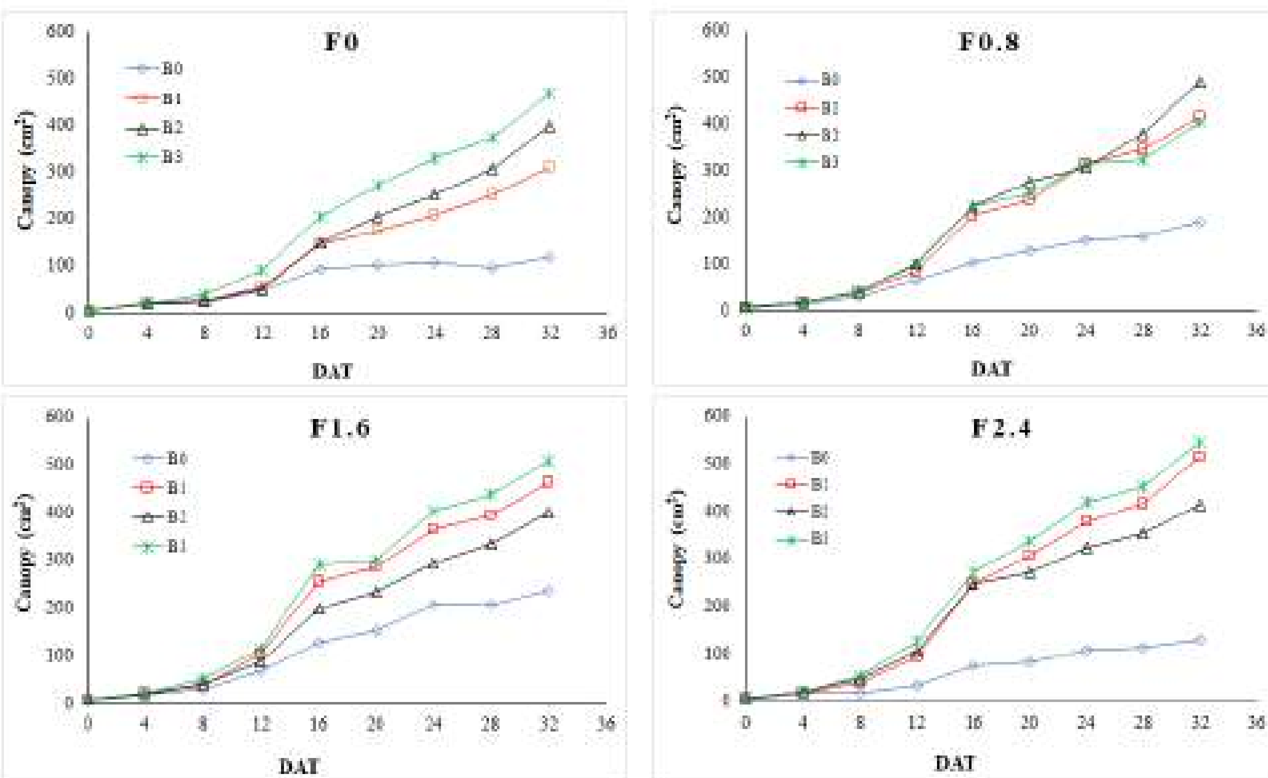

Figure 3. Development of canopy cover of Pak choi for different treatments.

Table 2. Effect of treatments on the leaf number, plant height, canopy cover, and crop yield at 32 DAT

Crop yield (g/pot)					
Biochar	F0	F0.6	F1.2	F1.8	Average
B0	7.4	9.8	13.7	6.2	9.3 c
B250	16.3	23.4	28.3	33.2	25.3 ab
B300	21.3	29.4	23.4	25.9	25.0 b
B350	26.4	26.8	33.5	35.7	30.6 a
Average	17.8 B	22.3 AB	24.7 A	25.2 A	
Plant height (cm)					
B0	15.7	16.3	18.6	14.4	16.3 b
B250	20.3	21.9	21.7	22.1	21.5 a
B300	20.9	22.5	20.6	21.2	21.3 a
B350	22.0	21.6	22.1	23.5	22.3 a
Average	19.7	20.6	20.8	20.3	
Leaf number					
B0	10	11	13	9	11 c
B250	15	16	15	17	16 bc
B300	15	18	16	17	17 ab
B350	17	17	19	18	18 a
Average	14	15	16	16	
Canopy cover (cm^2)					
B0	119.6	190.6	236.8	130.2	169.3 c
B250	309.0	415.6	461.8	511.5	424.5 ab
B300	397.8	478.4	400.2	406.1	420.6 b
B350	466.5	403.8	510.3	522.2	475.7 a
Average	323.2 B	372.1 AB	402.3 A	392.5 A	
Water productivity (g/L)					
Biochar	F0	F0.6	F1.2	F1.8	Average
B0	2.77	5.62	6.98	10.23	6.40 b
B250	4.37	9.49	12.74	10.90	9.37 a
B300	6.06	10.95	8.85	13.28	9.78 a
B350	2.69	13.56	8.94	15.16	10.09 a
Average	3.97 C	9.90 B	9.37 B	12.39 A	

Note: numbers followed by the same letter are not statistically different at $\alpha = 5\%$: lowercases are for column (biochar treatment), uppercases for row (Urea dose).

Table 3. Effect of treatments on the water productivity and fertiliser productivity (g/g).

Biochar	F0.6	F1.2	F1.8
B0	21.60 cde	15.48 ef	4.62 fg
B250	53.32 b	31.43 cd	25.42 cde
B300	73.79 a	24.78 cde	18.63 def
B350	53.39 b	35.87 c	27.59 cde

Note: numbers followed by the same letter are not statistically different at $\alpha = 5\%$.

The temperature in the greenhouse during the study was in average higher than that of normal situation, reaching 32.3 ℃ with a range of 26.7 to 43.1 and a deviation standard (SD) of 3.7 ℃. This condition, accompanied by low relative humidity (RH) at an average value of 58.4% with a range of minimum of 34% to maximum of 83% and SD of 10%, was an unfavorable environment for good plant growth.

DISCUSSION

Plant Development and Yield

Figures 1 to 3 show the growth of pak choi plants for 32 days which is indicated by plant parameters such as the number of leaves, plant height, and canopy area. From these pictures, it can be observed that the growth of Pak choi on growing media with no biochar amendment was always lower than that of plants grown on media amended with biochar at all doses of Urea fertiliser. This shows the superiority of biochar as a soil amendment. Pak choi production in this study was in the range of 9.3 to 30.6 g/plant on average (Table 2). Assuming a spacing plant of 20x25 cm (Wiangsamut & Koolpluksee, 2020), the maximum yield will be 6.12 t/ha. This figure is very close to the average productivity of Pak choi in Lampung which is 6.84 t/ha (BPS Provinsi Lampung, 2020). It, however, is still much lower than the study of (Wiangsamut & Koolpluksee, 2020) with a yield of 18.76 t/ha. The combination of acidic and infertile ultisol soil factors coupled with high temperature and low RH in the greenhouse may cause the low production of Pak choi plants.

Table 2 shows that the interaction factor of pyrolysis temperature of corncob biochar and Urea fertiliser dosage had no significant effect on the crop yield at the level of $\alpha = 0.05$. However, these two factors separately had a significant effect on the canopy area and yield of Pak coi plants ($\alpha = 0.05$). The higher the dose of fertiliser increased crop production. At low doses (0.6 g/pot) the effect of urea fertiliser was not significant. However, at higher doses (1.2 and 1.8 g/pot) the effect of Urea fertiliser was significant when compared to plants without fertiliser application. It is well known that nitrogen fertiliser is important to achieve high yield and good quality vegetables (Tei et al., 1999).

The application of biochar significantly increases the production of Pak choi plants by an average of 290% from 9.3 g/plant (without biochar) to 25.3 – 30.6 g/plant (with corncob biochar addition). From the table, it can be seen that the higher the pyrolysis temperature of corncobs gave a significant positive effect on crop yields. The highest yield (30.6 g) was obtained from growing media amended with biochar made at 350 °C. Higher pyrolysis temperatures produce biochar with more porous structure, higher specific surface area, and higher pore volume (Singh et al., 2010). These properties are beneficial for biochar as a soil amendment.

Leaves Number and Plant Height

Table 2 also shows interesting findings where Urea fertiliser dose is not significant on the number of leaves and plant height of Pak choi. The number of leaves of Pak choi without fertiliser was 14 on average, not statistically different from that of fertiliser application (15-16). Likewise, plant height without fertiliser was 19.7 cm, not significantly different from that of grown with Urea (20.3 to 20.8 cm). This can be caused by too low fertiliser dose, considering that the soil is acidic and infertile, as shown in Table 1.

On the other hand, biochar was able to increase the number of leaves and plant height significantly. Plant height without biochar (16.3 cm) was significantly lower than plant height with biochar (21.3-21.5 cm). Application of biochar, regardless pyrolysis temperature, increased plant height between of 30.7 to 36.8% compared to control without biochar. Table 2 also shows that the higher the pyrolysis temperature gave a positive effect on the number of leaves but not on the plant height of Pak choi. Pak choi was transplanted when the plants have three true leaves. During growth, the leaves number increased by an average of 8 (without biochar) and 13-15 with biochar or leaf appearances of 0.40-0.47 d^{-1}. This gives an explanation that the pyrolysis temperature of biochar has a positive correlation with plant yields, one of which is through the increase in the number of leaves. The addition of biochar to nutrient-deficient soils increases plant growth and nutrient uptake more optimally.Our result is better than those reported by (Gunawan & Susylowati, 2013) with an increase of between 8 and 10 leaves.

Canopy Area

The effect of treatment on canopy area was similar to its effect on crop yields where fertiliser application of 0.6 g/pot was not statistically significant. At doses of Urea 1.2 and 1.8 the plant canopy area increased significantly compared to the plant canopy area without fertiliser. A relationship between N dose and leaf area index of corn and sunflower was reported where leaf area decreased under limited N concentration due to reduced photosynthesis by leaves, lower rates of leaf area development and increased leaf senescence (Massignam et al., 2011).

The canopy area is influenced by the number of leaves, the width of leaves, and leaves structure. Previously it was shown that the number of leaves and plant height were not affected by the dose of fertiliser. Thus, increasing the canopy area by the dose of fertiliser had implications for the increase in leaf width. The measurement results did prove that fertiliser addition resulted in a significant increase of leaf width with an average value of 6.71 cm without fertiliser and 7.56, 7.33, and 7.34 cm for plants with fertiliser doses of 0.6, 1.2, and 1.8 g/pot, respectively. The effect of fertiliser dose from 0.6 to 1.8 g/plant on the width of leaves was not statistically different at $\alpha = 0.05$. Similarly, biochar addition significantly increase leaf width from 5.23 cm (no biochar) to 7.83, 7.73, and 8.17 cm respectively for biochar addition with pyrolysis temperatures of 250, 300, and 350 °C. However, the effect of pyrolysis temperatures on the leaf width was also not significant at $\alpha = 0.05$. It was reported that the leaf area index of maize cultivated in soils amended with biochar was significantly larger than that of control (no biochar addition) treatment (Njoku et al., 2015).

Water and Fertiliser Productivity

Water productivity is the ratio of the crop yield to the total water supplied to the plant. Table 2 reveals that the Urea dose significantly increased water productivity by 312% from an average of 3.97 g/L (without fertiliser) to 12.39 g/L (urea dose 1.8 g/pot). Biochar addition also increase water productivity of Pak choi but at a lower rate with an average of 152% from 6.40 g/L (without biochar) to 9.37-10.09 g/L (with biochar). In addition, Table 2 shows that the effect of pyrolysis temperature on water productivity is not significant at the level of $\alpha = 0.05$.

We also calculated the effect of treatment on the fertiliser productivity of Pak choi, and the results are presented in Table 3. The interaction of the Urea dose and the pyrolysis temperature had a significant effect on fertiliser productivity. There is a consistent pattern where increasing the dose of fertiliser results in a decrease in fertiliser productivity in each biochar treatment. This means increase in the yield of Pak choi is lower than the rate of increase in the dose of urea fertiliser.

CONCLUSION

The use of corncob biochar as a soil enhancer in the cultivation of Pak choi has been carried out and shows the short-term effects of biochar on plant growth and yield. Without biochar addition, growing media produced much lower growth and yields than the media with biochar at all doses of Urea fertiliser. Planting media amended with biochar showed statistically better plant growth than without biochar for all growth parameters (number of leaves, plant height, canopy area, and crop yield). The yield of plants with the addition of biochar increased by 290% compared to that without biochar. Corncob pyrolysis temperature had a significant effect ($\alpha = 0.05$) on the parameters of plant height, the number of leaves, canopy area, and crop yields. Biochar pyrolysis temperature of 350 °C gave the best effect with the average yield of fresh top stover weight 30.6 g/plant, plant height 22.3 cm, leaf width 8.2 cm, number of leaves 17.4, water productivity 10.09 g/L, and fertiliser productivity 27.59-53.39 g/g depending on the fertiliser dose.

Acknowledgement

This work was financially supported by research grant from University of Lampung under contract number 1629/UN26.21/PN/2021 (21 April 2021).

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Application of Corncob Biochar and Urea for Pak choi (*Brassica rapa* L.) Cultivation: Short-Term Impact of Pyrolysis Temperature and Fertiliser Dose on Plant Growth and Yield

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Abstract

This study aimed to evaluate the effect of pyrolysis temperature of corncob biochar as soil amendment and urea fertiliser on the growth and yield of Pak choi. The dose of biochar was 90 g with total growing media of 3000 g. Two factors, namely pyrolysis temperature of biochar and fertiliser dose consisting of 4 levels each were randomly design with three replications. Pak choi cultivation was performed in pots (13 cm height, 19 cm upper diameter, and 13.5 cm bottom diameter). The results showed pyrolysis temperature was significant (α = 0.05) on growth parameters, fresh yield, water productivity and fertiliser productivity. Pyrolysis temperature of 350 °C resulted in the highest growth and production at an average yield of 30.6 g/plant, water productivity of 10.09 g/cm^3, and fertiliser productivity of 27.59-53.39 g/g depending on the dose.

Keywords: Biochar, Water productivity, Fertiliser productivity, Canopy, Leaf number

Introduction

Developed in China, Pak choi (*Brassica rapa* L) is a leafy, green vegetable now consumed nearly all over the world and an economically valuable commodity in many countries. In Indonesia, Pak choi is one of the favorite vegetables for various dishes and increasingly popular because of its short cultivation period with a harvesting time of 25-35 days after transplanting. Pak choi planted area gradually increased (1.8% during four years) from 61,133 ha in 2017 to 62.228 ha in 2020 (BPS, 2021). In the same period, Pak choi production increased 6.1% from 627,611 t/y (2017) to 665.668 t/y (2020) with average productivity of 10.7 t/ha. Pak choi productivity in Lampung (6.84 t/ha) is significantly lower than the national level. Inefficient cultivation techniques and infertile soil are important factors causing the low productivity in Lampung. Lampung Province has a wide expanse of dry upland acid soils of the ultisol type which generally are suboptimal land characterized by low cation exchange capacity (CEC), low organic matter, low water holding capacity, and high aluminium (Al) and high P fixation (Cornelissen et al., 2018). Therefore, efforts to increase soil fertility by appliying of soil amendment materials such as compost and biochar are of great importance.

The application of biochar as a soil amendment has been sharply increases during the last decade. Biochar is a porous, carbon-rich organic material produced through pyrolysis. Under very limited or no oxygen, pyrolysis converts biomass to a stable carbon (C) form that will stand for such a long time that it plays a vital role in C sequestration (Crombie et al., 2013). In soil, biochar acts as a sponge-like material with a high surface area that enhances water holding capacity thereby capable of reducing soil erosion (Hseu et al., 2014). Biochar increase nutrient and fertiliser retention and improves fertiliser efficiency (Liu et al., 2019). In addition, the ash content in biochar provides a liming effect that alleviate soil acidity (Cornelissen et al., 2018). Biochar also facilitates a good home for soil microorganisms that improve soil fertility (Lehmann et al., 2011). Interaction of these properties climaxes in the increased of soil productivity and plant yield. For example, even though no significant effect on grain yield, biochar application on rice increased soil pH, nitrate, mineral content (K, Ca, Mg, Mn), and CEC, while reducing Al (Carvalho et al., 2013). A combination of corncob biochar and low rate fertiliser (25% of recommended dose) in the humid season in Tanzania increased dry biomass yield by 83% and was comparable to that of full dose (Kiobia et al., 2019).

The application of biochar to increase the yield of Pak choi has been reported (Silitonga et al., 2018; Sugiyarto et al., 2021). Although crop yield did not significantly different due to biochar application, corncob biochar was reported to produce the highest number of Pak choi leaves compared to biochar from rice husk, coconut shell, oil palm waste, or coffee husk (Sugiyarto et al., 2021). Biochar application in acidic soil significantly increases Pak choi yield for five seasons regardless of nitrogen application (Yu et al., 2015). Application of rice husk biochar at medium (5% w/w) and high (10% w/w) dose increases aerial biomass yield of *Brassica rapa* L. in contaminated soils (Campos et al., 2021).

The effects of biochar application depend on feedstock type and pyrolysis conditions such as reaction time, temperature, and heating speed, (Tomczyk et al., 2020). Feedstock type dictates mineral composition, total organic carbon, and fixed carbon of biochar, while pyrolysis temperature determines pH and surface area of biochar (Zhao et al., 2013). Whereas, pyrolysis conditions determine biochar characteristics. Biochars produced using a top-lit updraft stove at high temperature are better for soil amendment due to their adsorption capacities and chemical stability as compared to those of low-temperature anaerobic charring using a retort (Kaal et al., 2017). This study, therefore, aims to provide information about the effect of the pyrolysis temperature of corncob biochar and its application on the yield of Pak choi, the effectiveness of using urea fertiliser, and water productivity.

Materials and Methods

Research was conducted in a greenhouse of the University of Lampung, Indonesia (5°22’7” S, 105°14’33” E) from November 2020 to February 2021. Corncob was chosen as feedstock for biochar because of its abundant availability in Lampung as Indonesia’s top three corn producing regions. The dry corncob was pyrolysed at three different temperatures (250, 300 and 350 ℃) using a covered drum externally heated using an LPG stove. Pyrolysis temperature was maintained by controlling flame intensity through the gas flowrate adjustment knob. The resulted biochar was ground and sieved using a 20 mesh (0,9 mm) screen. Ultisol soil collected from the subsoil layer within the university field laboratory had a composition of 29% sand, 30% silt, and 42% clay. It was sieved using a 3-mm soil screen and was then mixed thoroughly with biochar at a ratio of 90 g biochar with 2910 g soil to make a total of 3000 g growing media. Some properties of the soil and corncob biochar used in the experiment are presented in Table 1.

The growing media was filled into pots (13 cm height, 19 cm upper diameter, and 13.5 cm bottom diameter) and watered with pre-measured water to have a field capacity condition. Pak choi seed purchased from local farm shop was seedled for two weeks. Seedlings with a good vigor were transplanted into the prepared media. The pots were watered daily to replace the evapotranspiration loss as measured by the weighing method. Fertilisation was applied at 14 day after transplanting (DAT) and 21 DAT with half a dose for each application. The plants were harvested at 32 DAT.

Table 1. Properties of soil and biochar used in the experiment

Property	Value		Criteria	
Soil				
N-total (%)	0.04		Very low	
P-available (ppm)	11.85		Low	
C-organic (%)	0.38		Very low	
K-dd (mg/100gr)	0.09		Very low	
pH (initial)	4.5-5.5		Acid/medium	
pH (after harvesting)	6.0-8.0		Neutral	
Biochar	**250 ℃**	**300 ℃**		**350 ℃**
pH	9	10		10
Density (g/cm^3)	0.228	0.328		0.209

Experimental Design

The pot trial was conducted in a factorial design with two factors, namely pyrolysis temperature (no biochar, 250, 300 and 350 ℃) and urea dose (0, 0.6, 1.2, and 1.8 g/pot). All treatment combinations with three replications were completely randomised.

Analysis and Measurements

Parameters including water consumption, plant growth, canopy cover, and crop yield (fresh and dry basis) were monitored during plant growth. After harvesting, soil pH was observed. In addition, water productivity and fertiliser productivity were also calculated. The canopy cover was measured using the Canopy Cover Free application available on android. In this case, a styrofoam square of 60 cm side was used as a guide frame. The image was taken from such height that the guide frame is included precisely in the smartphone screen. After filtering, the canopy was presented as a percentage of the guide frame area. Water productivity (WP) and fertiliser productivity (FP) were calculated as fresh yield over water consumption and urea dose, respectively.

Statistical Analysis

Analysis of variance (ANOVA) and the least significant difference (LSD) test were performed using the SAS program ver. 9.13 to see the effect of treatment on the dependent variables at α = 5%.

RESULTS

Figures 1 to 3 show the development of leaf number, plant height, and canopy area up to day 32 (just before harvesting). In addition, Table 2 shows the treatment effect on plant parameters, namely number of leaves, plant height, canopy cover, fresh crop yield, and water productivity of Pak choi at 32 DAT. Table 3 is also presented to determine the effectiveness of the treatment on the fertiliser productivity.

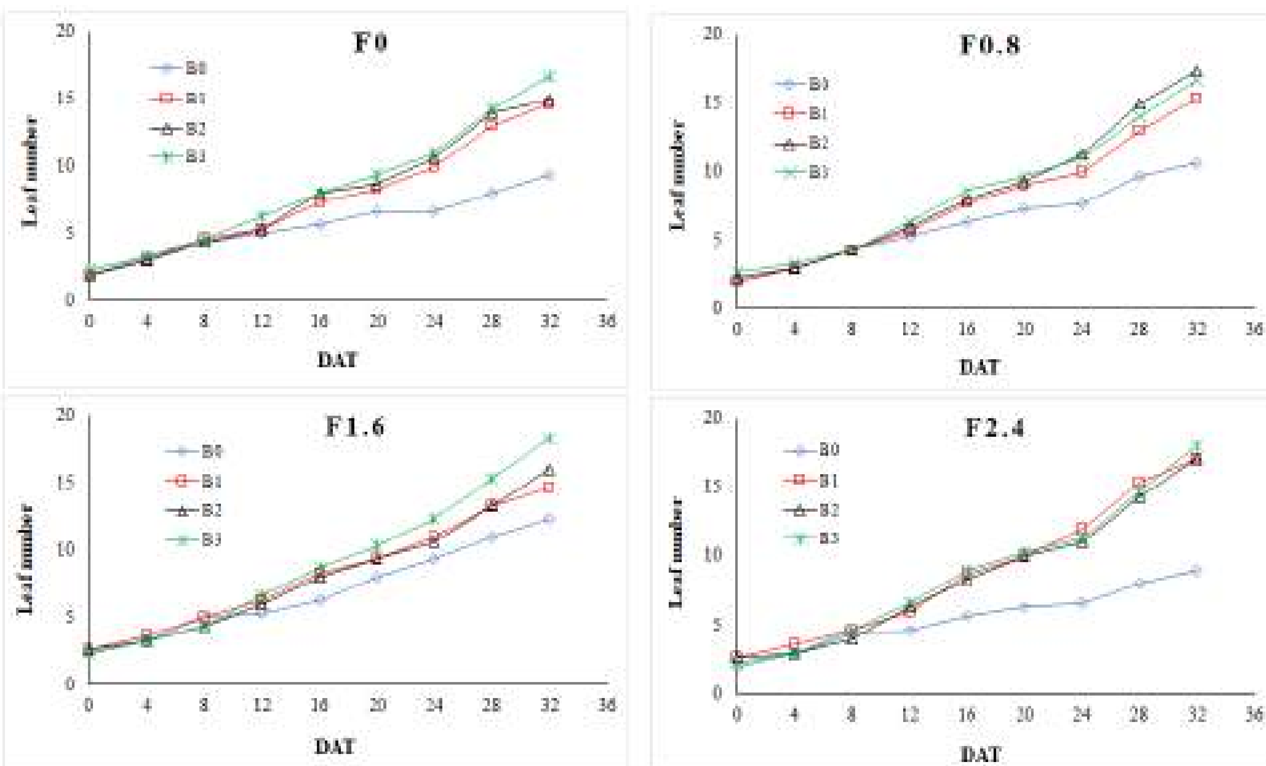

Figure 1. Development of leaf number of Pak choi for different treatments.

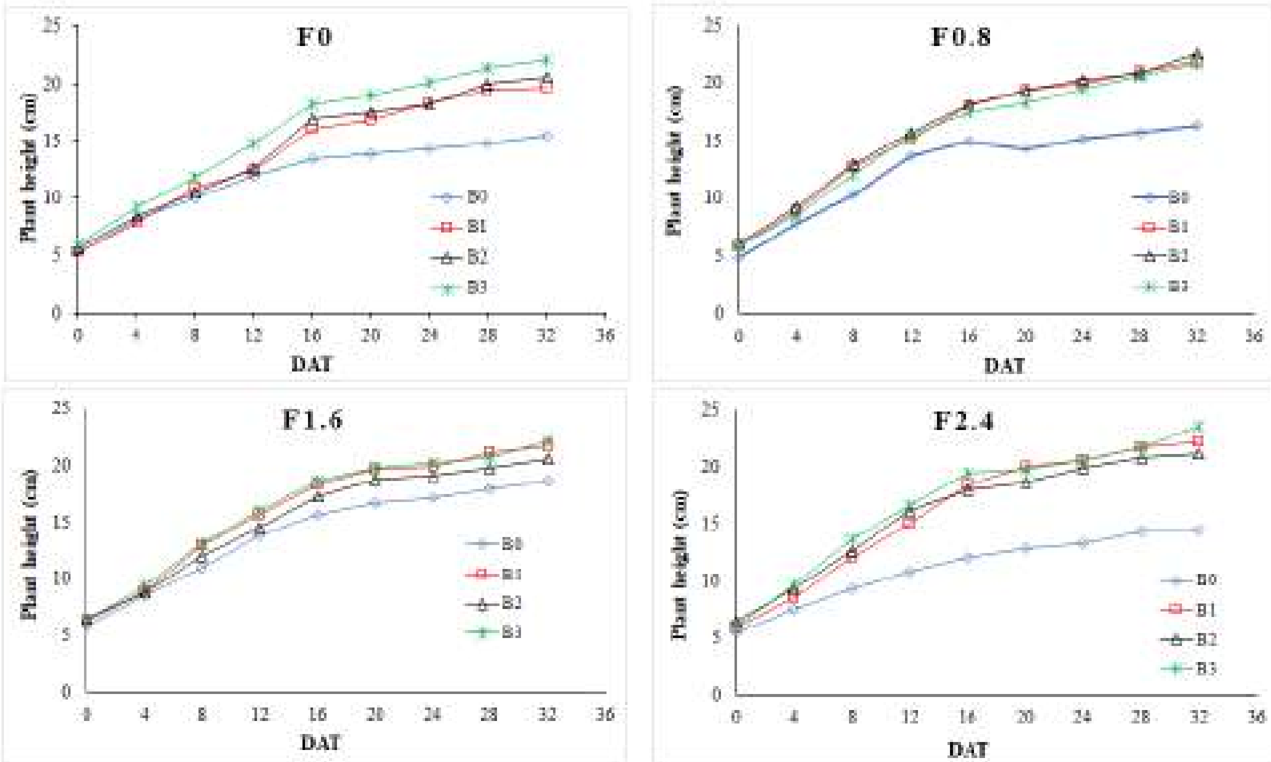

Figure 2. Development of plant height of Pak choi for different treatments.

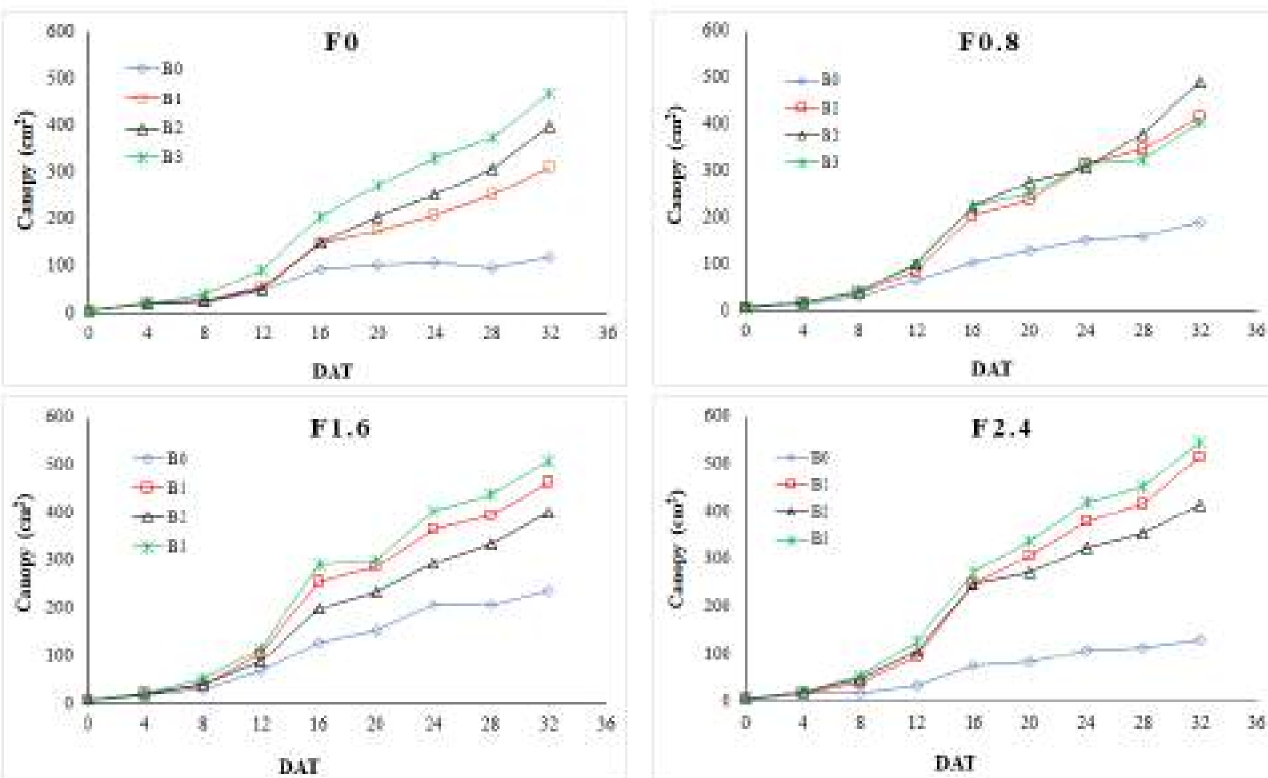

Figure 3. Development of canopy cover of Pak choi for different treatments.

Table 2. Effect of treatments on the leaf number, plant height, canopy cover, and crop yield at 32 DAT

Crop yield (g/pot)					
Biochar	F0	F0.6	F1.2	F1.8	Average
B0	7.4	9.8	13.7	6.2	9.3 c
B250	16.3	23.4	28.3	33.2	25.3 ab
B300	21.3	29.4	23.4	25.9	25.0 b
B350	26.4	26.8	33.5	35.7	30.6 a
Average	17.8 B	22.3 AB	24.7 A	25.2 A	
Plant height (cm)					
B0	15.7	16.3	18.6	14.4	16.3 b
B250	20.3	21.9	21.7	22.1	21.5 a
B300	20.9	22.5	20.6	21.2	21.3 a
B350	22.0	21.6	22.1	23.5	22.3 a
Average	19.7	20.6	20.8	20.3	
Leaf number					
B0	10	11	13	9	11 c
B250	15	16	15	17	16 bc
B300	15	18	16	17	17 ab
B350	17	17	19	18	18 a
Average	14	15	16	16	
Canopy cover (cm^2)					
B0	119.6	190.6	236.8	130.2	169.3 c
B250	309.0	415.6	461.8	511.5	424.5 ab
B300	397.8	478.4	400.2	406.1	420.6 b
B350	466.5	403.8	510.3	522.2	475.7 a
Average	323.2 B	372.1 AB	402.3 A	392.5 A	
Water productivity (g/L)					
Biochar	F0	F0.6	F1.2	F1.8	Average
B0	2.77	5.62	6.98	10.23	6.40 b
B250	4.37	9.49	12.74	10.90	9.37 a
B300	6.06	10.95	8.85	13.28	9.78 a
B350	2.69	13.56	8.94	15.16	10.09 a
Average	3.97 C	9.90 B	9.37 B	12.39 A	

Note: numbers followed by the same letter are not statistically different at α = 5%: lowercases are for column (biochar treatment), uppercases for row (Urea dose).

Table 3. Effect of treatments on the water productivity and fertiliser productivity (g/g).

Biochar	F0.6	F1.2	F1.8
B0	21.60 cde	15.48 ef	4.62 fg
B250	53.32 b	31.43 cd	25.42 cde
B300	73.79 a	24.78 cde	18.63 def
B350	53.39 b	35.87 c	27.59 cde

Note: numbers followed by the same letter are not statistically different at α = 5%.

The temperature in the greenhouse during the study was in average higher than that of normal situation, reaching 32.3 ℃ with a range of 26.7 to 43.1 and a deviation standard (SD) of 3.7 ℃. This condition, accompanied by low relative humidity (RH) at an average value of 58.4% with a range of minimum of 34% to maximum of 83% and SD of 10%, was an unfavorable environment for good plant growth.

DISCUSSION

Plant Development and Yield

Figures 1 to 3 show the growth of pak choi plants for 32 days which is indicated by plant parameters such as the number of leaves, plant height, and canopy area. From these pictures, it can be observed that the growth of Pak choi on growing media with no biochar amendment was always lower than that of plants grown on media amended with biochar at all doses of Urea fertiliser. This shows the superiority of biochar as a soil amendment. Pak choi production in this study was in the range of 9.3 to 30.6 g/plant on average (Table 2). Assuming a spacing plant of 20x25 cm (Wiangsamut & Koolpluksee, 2020), the maximum yield will be 6.12 t/ha. This figure is very close to the average productivity of Pak choi in Lampung which is 6.84 t/ha (BPS Provinsi Lampung, 2020). It, however, is still much lower than the study of (Wiangsamut & Koolpluksee, 2020) with a yield of 18.76 t/ha. The combination of acidic and infertile ultisol soil factors coupled with high temperature and low RH in the greenhouse may cause the low production of Pak choi plants.

Table 2 shows that the interaction factor of pyrolysis temperature of corncob biochar and Urea fertiliser dosage had no significant effect on the crop yield at the level of $\alpha = 0.05$. However, these two factors separately had a significant effect on the canopy area and yield of Pak coi plants ($\alpha = 0.05$). The higher the dose of fertiliser increased crop production. At low doses (0.6 g/pot) the effect of urea fertiliser was not significant. However, at higher doses (1.2 and 1.8 g/pot) the effect of Urea fertiliser was significant when compared to plants without fertiliser application. It is well known that nitrogen fertiliser is important to achieve high yield and good quality vegetables (Tei et al., 1999).

The application of biochar significantly increases the production of Pak choi plants by an average of 290% from 9.3 g/plant (without biochar) to 25.3 – 30.6 g/plant (with corncob biochar addition). From the table, it can be seen that the higher the pyrolysis temperature of corncobs gave a significant positive effect on crop yields. The highest yield (30.6 g) was obtained from growing media amended with biochar made at 350 °C. Higher pyrolysis temperatures produce biochar with more porous structure, higher specific surface area, and higher pore volume (Singh et al., 2010). These properties are beneficial for biochar as a soil amendment.

Leaves Number and Plant Height

Table 2 also shows interesting findings where Urea fertiliser dose is not significant on the number of leaves and plant height of Pak choi. The number of leaves of Pak choi without fertiliser was 14 on average, not statistically different from that of fertiliser application (15-16). Likewise, plant height without fertiliser was 19.7 cm, not significantly different from that of grown with Urea (20.3 to 20.8 cm). This can be caused by too low fertiliser dose, considering that the soil is acidic and infertile, as shown in Table 1.

On the other hand, biochar was able to increase the number of leaves and plant height significantly. Plant height without biochar (16.3 cm) was significantly lower than plant height with biochar (21.3-21.5 cm). Application of biochar, regardless pyrolysis temperature, increased plant height between of 30.7 to 36.8% compared to control without biochar. Table 2 also shows that the higher the pyrolysis temperature gave a positive effect on the number of leaves but not on the plant height of Pak choi. Pak choi was transplanted when the plants have three true leaves. During growth, the leaves number increased by an average of 8 (without biochar) and 13-15 with biochar or leaf appearances of 0.40-0.47 d^{-1}. This gives an explanation that the pyrolysis temperature of biochar has a positive correlation with plant yields, one of which is through the increase in the number of leaves. The addition of biochar to nutrient-deficient soils increases plant growth and nutrient uptake more optimally.Our result is better than those reported by (Gunawan & Susylowati, 2013) with an increase of between 8 and 10 leaves.

Canopy Area

The effect of treatment on canopy area was similar to its effect on crop yields where fertiliser application of 0.6 g/pot was not statistically significant. At doses of Urea 1.2 and 1.8 the plant canopy area increased significantly compared to the plant canopy area without fertiliser. A relationship between N dose and leaf area index of corn and sunflower was reported where leaf area decreased under limited N concentration due to reduced photosynthesis by leaves, lower rates of leaf area development and increased leaf senescence (Massignam et al., 2011).

The canopy area is influenced by the number of leaves, the width of leaves, and leaves structure. Previously it was shown that the number of leaves and plant height were not affected by the dose of fertiliser. Thus, increasing the canopy area by the dose of fertiliser had implications for the increase in leaf width. The measurement results did prove that fertiliser addition resulted in a significant increase of leaf width with an average value of 6.71 cm without fertiliser and 7.56, 7.33, and 7.34 cm for plants with fertiliser doses of 0.6, 1.2, and 1.8 g/pot, respectively. The effect of fertiliser dose from 0.6 to 1.8 g/plant on the width of leaves was not statistically different at $\alpha = 0.05$. Similarly, biochar addition significantly increase leaf width from 5.23 cm (no biochar) to 7.83, 7.73, and 8.17 cm respectively for biochar addition with pyrolysis temperatures of 250, 300, and 350 °C. However, the effect of pyrolysis temperatures on the leaf width was also not significant at $\alpha = 0.05$. It was reported that the leaf area index of maize cultivated in soils amended with biochar was significantly larger than that of control (no biochar addition) treatment (Njoku et al., 2015).

Water and Fertiliser Productivity

Water productivity is the ratio of the crop yield to the total water supplied to the plant. Table 2 reveals that the Urea dose significantly increased water productivity by 312% from an average of 3.97 g/L (without fertiliser) to 12.39 g/L (urea dose 1.8 g/pot). Biochar addition also increase water productivity of Pak choi but at a lower rate with an average of 152% from 6.40 g/L (without biochar) to 9.37-10.09 g/L (with biochar). In addition, Table 2 shows that the effect of pyrolysis temperature on water productivity is not significant at the level of $\alpha = 0.05$.

We also calculated the effect of treatment on the fertiliser productivity of Pak choi, and the results are presented in Table 3. The interaction of the Urea dose and the pyrolysis temperature had a significant effect on fertiliser productivity. There is a consistent pattern where increasing the dose of fertiliser results in a decrease in fertiliser productivity in each biochar treatment. This means increase in the yield of Pak choi is lower than the rate of increase in the dose of urea fertiliser.

CONCLUSION

The use of corncob biochar as a soil enhancer in the cultivation of Pak choi has been carried out and shows the short-term effects of biochar on plant growth and yield. Without biochar addition, growing media produced much lower growth and yields than the media with biochar at all doses of Urea fertiliser. Planting media amended with biochar showed statistically better plant growth than without biochar for all growth parameters (number of leaves, plant height, canopy area, and crop yield). The yield of plants with the addition of biochar increased by 290% compared to that without biochar. Corncob pyrolysis temperature had a significant effect ($\alpha = 0.05$) on the parameters of plant height, the number of leaves, canopy area, and crop yields. Biochar pyrolysis temperature of 350 °C gave the best effect with the average yield of fresh top stover weight 30.6 g/plant, plant height 22.3 cm, leaf width 8.2 cm, number of leaves 17.4, water productivity 10.09 g/L, and fertiliser productivity 27.59-53.39 g/g depending on the fertiliser dose.

Acknowledgement

This work was financially supported by research grant from University of Lampung under contract number 1629/UN26.21/PN/2021 (21 April 2021).

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